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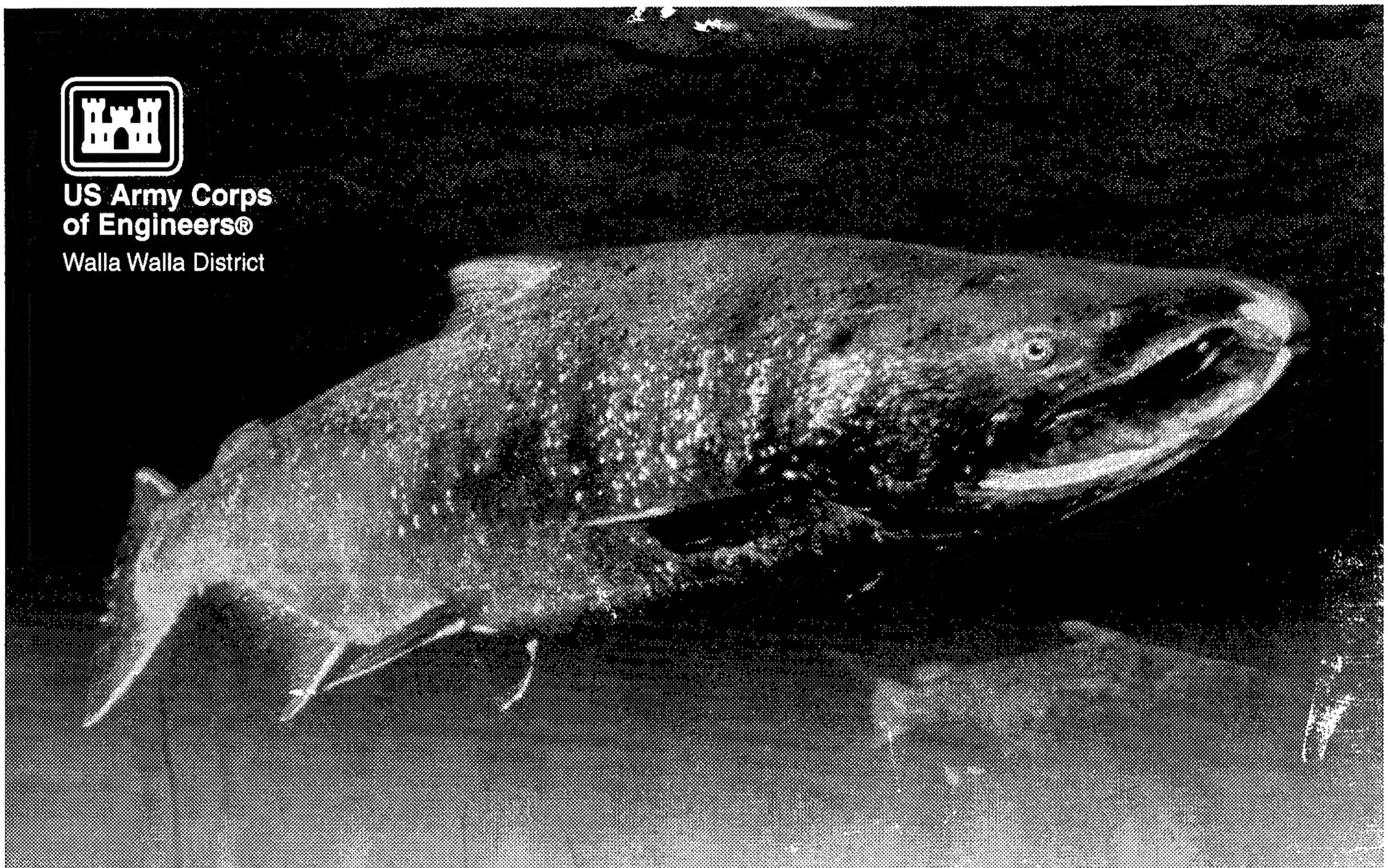

DRAFT
Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

APPENDIX P
Air Quality

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December 1999

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13. ABSTRACT *(Maximum 200 words)*
The Corps of Engineers along with the Bonneville Power Administration, US Environmental Protection Agency, and US Bureau of Reclamation as cooperating agencies, analyzed four general alternatives intended to provide information on the technical, environmental, and economic effects of actions related to improving juvenile salmon passage. The four alternatives include Alternative 1 - Existing Conditions (the no-action alternative) and three different ways to further improve juvenile salmon passage. The action alternatives are: Alternative 2 - Maximum Transport of Juvenile Salmon, Alternative 3 - Major System Improvements, and Alternative 4 - Dam Breaching. Comparison of the alternatives by all of the factors assessed in the study has not offered a clear-cut recommendation at this time. It is the Corps of Engineer's intent to recommend a preferred plan of action in the Final FR/EIS.

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FEASIBILITY STUDY DOCUMENTATION

Document Title	
Summary to the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A	Anadromous Fish
Appendix B	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F	Hydrology/Hydraulics and Sedimentation
Appendix G	Hydroregulations
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Appendix Q	Tribal Consultation/Coordination
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Appendix T	Biological Assessment
Appendix U	Clean Water Act, Section 404(b)(1) Evaluation

The documents listed above, as well as supporting technical reports and other study information, are available on our website at www.nww.usace.army.mil. Copies of these documents are also available for public review at various city, county, and regional libraries.

FOREWORD

This appendix is one part of the overall effort of the U.S. Army Corps of Engineers (Corps) to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

Please note that this document is a DRAFT appendix and is subject to change and/or revision based on information received through comments, hearings, workshops, etc. After the comment period ends and hearings conclude a Final FR/EIS with Appendices is planned.

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input, comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the Draft FR/EIS and Appendices, therefore, not all the opinions and/or findings herein may reflect the official policy or position of the Corps.

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997)

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System. The Biological Opinion established measures to halt and reverse the declines of these listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The U.S. Army Corps of Engineers (Corps) implemented a study after NMFS's Biological Opinion in 1995 of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) and assist in their recovery.

Development of Alternatives

The Corps completed an interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities. Based in part on a screening of actions conducted in the interim report, the study now focuses on four courses of action:

- Existing conditions (currently planned fish programs)
- System improvements with maximum collection and transport of juveniles (without major system improvements such as surface bypass collectors)
- System improvements with maximum collection and transport of juveniles (with major system improvements such as surface bypass collectors)
- Dam breaching or permanent drawdown to natural river levels for all reservoirs

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has lead to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve four major alternatives that were derived out of three major pathways. The four alternatives are:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2'	A-2c	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue. Project operations, including all ancillary facilities such as fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation would remain the same unless modified through future actions. Adult and juvenile fish passage facilities would continue to operate.

The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass collection (SBC) facilities in conjunction with extended submersible bar screens (ESBS) and a behavioral guidance system (BGS). The intent of these facilities is to provide more effective diversion of juvenile fish away from the turbines. Under this alternative the number of fish collected and delivered to upgraded transportation facilities would be maximized at Lower Granite, the most upstream dam, where up to 90 percent of the fish would be collected and transported.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams allowing the reservoirs to be drained and resulting in a free-flowing river that would remain unimpounded. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational, and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and Habitat Management Units (HMUs) would also change although the extent of change would probably be small and is not known at this time. Project development, design, and construction span a period of nine years. The first three to four years concentrate on the engineering and design processes. The embankments of the four dams are breached during two construction seasons at year 4-5 in the process. Construction work dealing with mitigation and restoration of various facilities adjacent to the reservoirs follows dam breaching for three to four years.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.

BOUNDARIES

State

County

KM 300 100 0

MILES 0 7.5 15 30

GEOGRAPHIC INFORMATION SYSTEMS
Corps of Engineers
Walla Walla District

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DRAFT

Lower Snake River
Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

1999

GIS Analysts & Graphic Assembly: Applied Technology Team (CENWW-PM-PD-E)
g:\regional\reg\plates\lsr\jsmeis\lsrg\lsrgbmgm.dgn:GISFILE PLOTTED: 25 OCT 1999

ABSTRACT

Technical Appendix P, Air Quality, presents an analysis of the project-related consequences of implementing alternatives considered in the Lower Snake River Juvenile Salmon Migration Feasibility Study. The air quality issues evaluated are primarily associated with the Natural River Drawdown Pathway and include:

- Fugitive dust emissions resulting from deconstruction of the dams
- The change in the quantity and distribution of vehicle emissions as commodities are shifted from barges to trains and trucks
- Fugitive dust emissions resulting from dry exposed lake sediments during high wind speed events
- Atmospheric emissions associated with replacement power generation by thermal power plants.

The air quality analysis required extensive input from the Transportation and Power studies by the Drawdown Regional Economic Workgroup (DREW) that were undertaken as part of the Technical Appendix I, Economics. The air quality in and around the lower Snake River is generally good and achieves all state and national ambient air quality standards. Industrial operations, woodsmoke, road dust, and windblown dust from disturbed surfaces (such as agricultural fields) are the primary sources of fugitive dust in the atmosphere. Throughout the arid and semi-arid portions of eastern Washington, wind erosion is the primary cause of dust emissions, often associated with dryland farming. Climatic conditions in the lower Snake River area are characterized by large seasonal temperature differences, low precipitation, and relatively minimal cloud cover conditions that tend to enhance wind erosion of surface soils.

No emission increases are estimated for the Existing Systems Pathway. Under this alternative, Snake River barge traffic would continue, and new power plants would continue to be built as power demand increases. Minor construction-related emission increases are anticipated for the Major System Improvement Pathway. As with the Existing Systems Pathway, Snake River barge traffic would continue and new power plants would continue to be built as power demand increases. The Natural River Drawdown Pathway would result in excavation and deconstruction fugitive emissions, fugitive dust from exposed reservoir sediments, emissions associated with the loss of barge transportation, and emissions associated with replacement power generation. While mitigation measures such as revegetation of exposed reservoir bottoms and spraying haul roads with water could reduce the potential for fugitive dust emissions, the adverse effects of dam breaching cannot be avoided. New replacement power plants would increase local emissions wherever they are built, and they would be subject to emission controls defined by best available control technology (BACT).

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Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

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Appendix P

Air Quality

Produced by

Kennedy/Jenks Consultants

Produced for

U.S. Army Corps of Engineers

Walla Walla District

Completed December 1999
Revised and released for review
with Draft FR/EIS
December 1999

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Centigrade
°F	Degrees Fahrenheit
$\mu g/m^3$	Micrograms per cubic meter
AAQS	Ambient air quality standards
BACT	Best Available Control Technology
BPA	Bonneville Power Administration
Btu	British thermal unit
CCAP	U.S. Climate Change Action Plan
CEMS	Continuous emission monitoring system
CFC	Chlorofluorocarbons
CFR	Code of Federal Regulations
CH_4	Methane
cm	Centimeter
CO	Carbon monoxide
CO_2	Carbon dioxide
Corps	U.S. Army Corps of Engineers
CP^3	Columbia Plateau PM_{10} Program
cy	Cubic yard
DREW	Drawdown Regional Economic Workgroup
E	Emissions
EC	Energy consumption
Ecology	Washington State Department of Ecology
EF	Emission factor
EPA	U.S. Environmental Protection Agency
EWITS	Eastern Washington Intermodal Transportation Study
FCAA	Federal Clean Air Act
FCCC	Framework Convention on Climate Change
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
g	Grams
gal	Gallon
GAMS	General Algebraic Modeling System
GHG	Greenhouse gases
GIS	Geographic Information System
HAP	Hazardous air pollutant
HCFC	Partially halogenated fluorocarbons
hp	Horsepower
HRSG	heat recovery steam generator
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producers
k	Dimensionless aerodynamic particle size multiplier
kg	Kilograms
kg/hour	Kilograms per hour
km	Kilometer
km/hour	Kilometers per hour

ACRONYMS AND ABBREVIATIONS

lb	Pound
lb/gal	Pounds per gallon
m	Meter
M	Moisture content
m/sec	Meters per second
m^2	Square meters
m^3	Cubic meters
mm	Millimeter
mph	Miles per hour
MT	Metric ton (1,000 kgs)
MTY	Metric tons per year
MW	Megawatts
N_2O	Nitrous oxide
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	Ammonia
NO_2	Nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen oxides
NSR	New Source Review
O_3	Ozone
ODEQ	Oregon Department of Environmental Quality
p	Number of days per year with measurable precipitation
Pb	Lead
PG&E	Pacific Gas and Electric
PM	Particulate matter
PM_{10}	Small particulate matter
$PM_{2.5}$	Fine particulate matter
ppm	Parts per million
PROSYM	Power system model
S	Mean vehicle speed
s	Silt content
SBC	Surface bypass collector
SCE	Southern California Edison
SCR	Selective catalytic reduction
SDG&E	San Diego Gas and Electric
SO_2	Sulfur dioxide
SOR	System Operation Review
TAP	Toxic air pollutants
TPY	Ton per year
TSP	Total suspended particulates
u	Mean wind speed
u_{fm}	Fastest mile
u_{fv}	Frictional velocity
u_{tv}	Threshold frictional velocity

ACRONYMS AND ABBREVIATIONS

VKT	Vehicle kilometers traveled
VMT	Vehicle miles traveled
VOC	Volatile organic compounds
W	Mean vehicle weight
WAC	Washington Administrative Code
WEAQP	Wind Erosion Air Quality Project
WSCC	Western System Coordinating Council
WSDOT	Washington State Department of Transportation

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Executive Summary

In response to the National Marine Fisheries Service 1995 Biological Opinion concerning the operation of the Columbia River power system, the U.S. Army Corps of Engineers is studying structural and operational alternatives to improve the downstream migration of juvenile salmon through the lower Snake River dams. Implementation of any of the proposed pathways would result in changes to the air quality of the lower Snake River area. The information in this appendix may be used to compare the Lower Snake River Juvenile Salmon Migration Feasibility Report pathways from an air quality perspective, and may be used with other investigations to develop a comprehensive picture of the consequences of the pathways.

This analysis assumes that air quality impacts associated with the first two pathways would be identical and focuses on the remaining pathways:

- Existing System
- Major System Improvements
- Natural River Drawdown

The Existing System Pathway represents current conditions during a baseline year (generally 2010). The greatest change in emissions would be associated with the Natural River Drawdown Pathway. Air quality issues associated with this pathway define the areas to be investigated. These same areas are investigated for the other pathways to define baseline conditions. Air quality issues associated with the Natural River Drawdown Pathway include the following:

- Fugitive dust emissions generated during deconstruction of the dams
- The change in the quantity and distribution of vehicle emissions as Snake River commence shifts from barges to trains and trucks
- Fugitive emissions resulting from dry exposed lake sediments during storm generated high wind speeds
- Atmospheric emissions from new thermal power plants built to replace hydropower.

The technical sections of this appendix present and summarizes emissions for each of the four issues by Pathway. The summary below presents emissions for each issue, organized by Pathway.

Construction and Deconstruction Fugitive Dust

The **Existing System** Pathway would not result in demolition of the lower Snake River dams. Therefore, there would not be any deconstruction fugitive dust emissions. Although the dams would remain intact for the **Major System Improvements** Pathway, there would be some construction activities. Construction-related emissions would be very small and would be limited to particulate matter, which has been conservatively estimated at 907.2 kilograms (kgs) per year (1 ton per year [tpy]). Construction equipment tailpipe emissions were not estimated.

The **Natural River** Pathway would result in deconstruction of the four lower Snake River dams. Deconstruction-related emissions for this pathway include fugitive emissions from material handling

activities such as hauling, dumping, bulldozing, and grading. The PM_{10} emission estimates were derived from EPA emission factors, equipment operating hours, and the volume of material to be excavated. They account for construction mitigation measures such as water-spraying haul roads. Since it is likely that all four dams would be deconstructed in 2 years, PM_{10} emissions are estimated to be half of what is presented, or half of 225,788.8 kgs (304 tons). Construction vehicle tailpipe emissions were not estimated.

Transportation Emissions

In 1994, over 3.81 billion kgs (4.2 million tons) of freight passed through the Ice Harbor locks. About 80 percent of the river commerce is the down river transportation of farm products, especially the grain harvest. The Natural River Drawdown Pathway would shift this commerce from barges to trains and trucks. Snake River towboat emissions would be replaced with locomotive and truck emissions. The distribution of transportation emissions would shift from the waterway to highways and railroads.

Transportation-related emissions were estimated by modeling the flow of grain from farms through intermediate elevators to barges, trains, and trucks. EPA emission factors were used to convert bushel-miles or ton-miles predicted by the models to tons of emitted pollutants. The emission estimates were escalated to account for all commodities (not just grain), increases in commerce by 2010, and the return of empty containers. Transportation-related emissions for the Existing System and Major System Improvements pathways would represent base-case emissions for 2010. Natural River Pathways emissions are for 2010 without the Snake River waterway. The estimated emissions and the change in emissions are as follows:

	Emissions (tons)				
Pollutant	**CO**	**NO_x**	**PM_{10}**	**SO_2**	**VOC**
Existing System	218	1,586	49	245	280
Major System Improvement	218	1,586	49	245	280
Natural River Drawdown	203	1,566	58	174	370
Percent Change	(6.9)	(1.3)	18.4	(29.0)	32.1

Grain shipped on the Snake River is first trucked to elevators at river ports. Without the river the grain would be trucked to elevators located next to railroads, or to other ports on the Columbia River. Without the Snake River waterway, truck traffic would become concentrated on roads that lead to and from the Tri-Cities, especially state route 395. Local and rural roads east of Pasco would also receive much of the increased truck traffic. The modeled number of bushels of grain, with and without the Snake River waterway, may be used to estimate the change in the number of trucks on major eastern Washington highways, as illustrated on page P ES-3.

The greatest increase in truck traffic would take place along roads that are already heavily traveled. Traffic along highways used to haul grain to river ports would decrease. Truck traffic along little-used roads may double.

All transportation-related emissions would continue to decline in the future as fuel efficiencies improve and as national emission standards become effective. Emissions standards for locomotives would take effect in 2000. Emission standards for compression-ignition marine engines are

Highway	Intersection	Number of Trucks		Number of Trucks Per Day			Percent Change
		With Snake River	Without Snake River	Current	Change with Drawdown	Projected	
SR 395	SR 26	19,615	60,231	1,925	223	2,148	12
	SR 260	19,615	60,231	2,000	223	2,223	11
SR 127	SR 26	18,462	1,154	260	(95)	165	(36)
SR 195	SR 26	51,577	2,308	1,173	(270)	903	(23)
SR 26	SR 395	6,923	31,385	336	134	470	40
	SR 261	6,923	31,385	200	134	334	67
	SR 127	18,462	31,385	504	71	575	14
	SR 195	17,308	21,923	650	25	675	4

proposed to become effective in 2004. And the first phase of a proposed strategy to reduce emissions from heavy-duty vehicles would become effective in 2004.

Windblown Fugitive Dust

Windblown dust would continue to be the major air quality problem in eastern Washington. Dust storms would continue to sweep the region. Under the Existing System and Major System Improvement Pathways, the sources of dust would be rangeland, irrigated agricultural land, and dry agricultural lands, including fallow lands and harvested lands with crop residue. The period when these lands are most susceptible to erosion is September through November, when the crops have been harvested and before the start of winter rains. During this period, about 10 storms per year can be expected to produce fugitive emissions of varying intensity. The Columbia Plateau PM_{10} Program (CP^3) has studied windblown dust and agricultural practices that would reduce emissions. Four of the larger storms from 1990 through 1993 were modeled by CP^3 to estimate emissions during these events and the resulting concentrations. Particulate matter emitted from between 0.809 and 2.023 hectares (2 and 5 million acres) ranged from 10.9 million kgs to 21.32 million kgs (12,000 to 235,000 tons) per event. Daily PM_{10} concentrations measured in the Kennewick and Spokane areas were between 126 and 1,166 $\mu g/m^3$ (the air quality standard is 150 $\mu g/m^3$). PM_{10} concentrations in the area of the Ice Harbor and Lower Monumental dams were predicted to be about 2,400 $\mu g/m^3$ during these storms.

The Natural River Pathway would eliminate the lower Snake River reservoirs, creating four large areas of dry lake sediments. Until seeding could establish a vegetative cover, the sediments would be susceptible to wind erosion. If strong winds such as those modeled by CP^3 occurred when the dry reservoir sediments were unprotected, PM_{10} emissions of between 353,808 and 3.52 million kgs (390 and 3,880 tons) per storm could be expected. These emissions would be 0.4 to 13 percent of the total emissions from agricultural lands.

Many of the individual storms would produce less than 181,440 kgs (200 tons) of PM_{10} from all four dry reservoirs. All four dry reservoirs exposed for a year would emit about 5.71 million kgs (6,290 tons) of PM_{10}. These estimates include mitigation through seeding. Tests at Owens Lake in California indicate that a 99 percent reduction in emissions is possible with only 50 percent of the dry sediments covered with vegetation. There are three phases of drill seeding that follow the initial

application of seed and fertilizer by aerial methods. The Corps would take measures to prohibit recreational vehicles on the dry sediments from breaking the surface crust and providing more material susceptible to erosion. The emission estimates include a 90 percent reduction factor for mitigation.

Another Lower Snake River Juvenile Salmon Migration Feasibility study identified areas where contaminated sediments exceed sediment criteria for dioxin, manganese, and total DDT. Data available at this time are insufficient to estimate potential airborne concentrations of these pollutants. Dispersion modeling of PM_{10} emissions from the reservoirs has yet to be performed.

Replacement Power Emissions

Hydropower would be available with the Existing System and Major System Improvement Pathways. However, demand for power will continue, requiring additional generating capacity. The loss of the lower Snake River dams would affect the generating resources of the Western System Coordinating Council. The Technical Report on Hydropower Costs and Benefits evaluated the need for additional generating capacity throughout the WSCC. Emissions from approximately 2,000 generating units were estimated from the number of hours each unit would be projected to operate and the hourly CO_2, NO_x, and SO_2 emission rates. The emission estimates represent the 2010 and include additional natural-gas-fired, combined-cycle power plants. CO, PM_{10}, VOC, benzene, and formaldehyde emissions were estimated from the projected emissions and EPA emission factors for various fuels.

The Hydropower Costs and Benefits Report evaluated costs associated with replacing power generated by the lower Snake River dams and concluded that it is not necessary to replace all 3,500 MW of generating capacity. The most likely scenario with dam breaching is construction of 1,550 MW of generating capacity somewhere in the Pacific Northwest by 2010. The most cost efficient power plants to build and operate are natural-gas-fired, combined-cycle plants with combustion turbines. Emissions for the Natural River Pathway were estimated for all generating units in the WSCC. Estimated emissions for all three pathways and the change in emissions with the Natural River Pathway are as follows:

	Emissions (thousands of tons)							
Pathway	**CO**	**CO_2**	**NO_x**	**PM_{10}**	**SO_2**	**VOC**	**Benzene**	**Formaldehyde**
Existing System	404	414,234	58	49	457	1	0.004	0.04
Major System Improvement	404	414,234	58	49	457	1	0.004	0.04
Natural River	408	418,421	58	49	459	1	0.004	0.04
Percent Increase	1.0	1.0	0.3	0.4	0.4	0.2	0.4	0.005

In the 7-year period from 1990 to 1997, U.S. CO_2 emissions increased from 4.93 million kgs to 5.46 million kgs (5,433 to 6,014 million tons), an increase of about 11 percent. If greenhouse gas emissions continue to increase at this rate, CO_2 emissions will reach 6.68 million kgs (7,367 million tons) by 2011. Western U.S. electric utility CO_2 emissions, following drawdown, would represent 5.7 percent of the national CO_2 emissions.

The most predominant type of thermal power plants recently added to the WSCC has been natural-gas-fired, combined-cycle plants with combustion turbines. Nine of these plants have been

constructed in Oregon and Washington since 1991, and another seven are planned. Because of their low cost, abundance of suitable sites, and favorable technical characteristics, natural-gas-fired, combined-cycle plants are the most likely power plant to be built in the near future.

The hydropower study team concluded that the most favorable locations to meet power demand and transmission reliability needs are as follows:

Location	Number of Combined Cycle Plants	Approximate Size of Individual Plants
Tri-Cities area, Washington	2	250 MW
Hermiston, Oregon	1	250 MW
Puget Sound area, Washington	3	250 MW

The above locations represent the best locations from a systems approach. Because the actual site would be decided by market conditions, it was projected for this study that power producers would build plants at these locations. However, there is a high degree of uncertainty regarding specific siting and timing of plant construction. Design characteristics of these plants will not be available for a number of years.

Replacement power plants would likely share many of the characteristics of recently constructed and planned power plants. These plants have at least two units, and the average output is about 340 MW. Turbine emissions would be controlled by any of a number of technologies. Steam or water may be injected into the combustion chambers to control NO_x emissions. Further NO_x control is obtained with use of low NO_x burners. Selective catalytic reduction (SCR) using ammonia would further reduce NO_x emissions. CO is controlled with good combustion and sometimes SCR technologies. PM_{10} and SO_2 emissions are controlled by use of clean fuels such as natural gas. New power plants will be subject to new source review and must demonstrate the use of best available control technology. Criteria air pollutants emitted from combustion turbines must also demonstrate compliance with National Emission Standards. National Emission Standards for Hazardous Air Pollutants are proposed for combustion turbines. Average annual emissions from the recently constructed and planned power plants are as follows:

Pollutant	CO	NO_x	PM_{10}	SO_2	VOC	Ammonia	Formaldehyde
Emissions (tons)	336	322	72	25	41	100	5

Ambient concentrations resulting from the power plants were predicted as part of the air quality permitting process. The concentrations were all lower than the national, state, and local ambient air quality standards.

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1. Introduction: Scope and Issues Development

The Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) provides an assessment of the measures intended to facilitate migration of juvenile salmon through the lower Snake River. Implementation of the proposed measures would result in air quality-related effects. The purpose of this Air Quality Appendix is to estimate changes in emissions directly related to breaching of the four lower Snake River Dams, for all alternatives being considered. In several instances, emission sources are located in air sheds other than along lower Snake River. Three pathways are investigated:

Existing System (Base Case)—The status of the lower Snake River reservoirs and hydrofacilities would remain unchanged. Emissions estimated for this pathway represent current conditions or a baseline year.

Major System Improvements—Collection and bypass structures would be constructed to enhance fish passage for all hydropower facilities. Barge transportation and power generation would continue unchanged.

Natural River Drawdown—The four lower Snake River hydropower facilities would be breached, restoring the river to natural conditions. Barge transportation and hydropower would be replaced with alternatives.

The air quality issues related to the Lower Snake River Juvenile Salmon Migration Feasibility Study are:

- Fugitive dust emissions resulting from deconstruction of the dams
- The change in the quantity and distribution of vehicle emissions as commodities are shifted from barges to trains and trucks
- Fugitive dust emissions resulting from dry exposed lake sediments during high wind speed events
- Atmospheric emissions associated with replacement power generation by thermal power plants

This appendix contains eight sections. Section 1 summarizes the air quality issues associated with the Feasibility Study and provides an overview of the study process. Section 2 describes the Federal and state programs that regulate air quality in the region of the lower Snake River, and discuss the air quality standards relevant to the analysis. The climatology and existing air quality of the region are also described. Section 3 presents the methods that this study uses for the air quality analysis. Section 4 presents the study results for the Feasibility Study pathways and potential mitigation measures. Section 5 compares the air quality impacts across the pathways. Sections 6 and 7 contain the references and glossary, respectively. Technical annexes A, B, and C that support the analysis are also included.

1.1 Issues Raised During the Scoping Process

The multi-agency System Operation Review (SOR) of the Columbia and Snake rivers included an analysis of the consequences to air quality resulting from the annual or permanent drawdown of reservoirs (Bonneville Power Administration [BPA]; U.S. Army Corps of Engineers [Corps]; and Bureau of Reclamation, 1995, SOR Appendix B). This analysis builds on the SOR work while focusing on the four lower Snake River dams. Some of the air quality issues identified during the SOR have been carried over to this study.

A number of additional air quality issues related to the Natural River Drawdown Pathway have been identified, including the following:

- Cumulative impacts of new and existing power plants
- Greenhouse gases (GHGs) and hazardous air pollutants (HAPs) from replacement power generation
- Site-specific data for characterizing air quality impacts
- Mobile source emission impacts on existing highways and roadways
- Cumulative impacts of demolishing more than one dam at a time
- Contaminants potentially present in reservoir sediments that may become airborne during high wind speed events.

The objective of this appendix is to provide a basis to compare impacts of the Feasibility Study pathways from an air quality perspective. This is accomplished by estimating air emissions resulting from pathway-related activities. However, these emissions may have undesirable impacts if they occur in sensitive areas or affect sensitive populations. Air emissions that result from pathway-related activities are subject to applicable local, state, and federal air quality regulations. In the case of power plants constructed to replace lost hydropower, the emissions and corresponding ambient concentrations are defined in this Appendix by examples obtained from recently permitted projects. Three recently permitted power plants in the Pacific Northwest may be constructed if demand for power rises. Projected emissions and predicted concentrations from these projects are included in this analysis. Additional power plants may be needed if the lower Snake River hydropower plants are removed. According to the Power System Analysis (DREW, 1999a), some new thermal power plants would be sited for power grid stability. Other power plants would be sited according to resource availability, proximity to transmission lines, power demand, and environmental considerations. Data required for a detailed impact analysis suitable for air emissions permit applications includes, at a minimum, the size and location of the replacement power plants. These data will not be known for many years. A detailed analysis that includes these hypothetical plants and the cumulative impacts of all the new power plants is not possible at this time.

A more in depth analysis and data collection is planned, if Natural River Drawdown is selected, in the following air quality areas:

- A configuration of the sources
- The schedule and duration of the deconstruction, drawdown, and revegetation [A spring drawdown and revegetation would produce fewer emissions.]
- The potential population at risk from emissions

- Site-specific data including meteorological data suitable for dispersion modeling, silt and moisture content of the excavated material and dry sediments, and the surface extent of contaminated sediments.

The concentration and location of contaminated sediments has only recently been made available. However, the data are averages of the top 0.6096 M (2 feet) of sediments, not sediment surface concentrations. Additional work is required before the sediment data can be incorporated into the air quality analysis.

To the extent possible, GHG and HAP emissions have been incorporated into the air quality analysis.

1.2 The Study Process

Air quality is not a major resource use of the lower Snake River. Consequently, the air quality study process differed from that of most of the other resource topics. Although the air quality analysis required little coordination among the other work groups, the analysis did require input from a number of other study groups. The Transportation Analysis (DREW, 1999b) provided transportation miles for calculating vehicle emissions. The Power System Analysis (DREW, 1999a) provided existing and projected emissions for thermal power plants. The Existing Systems and Major System Improvements Engineering Appendix (Appendix E) provides descriptions of construction activities planned for the Major System Improvements. The Natural River Drawdown Engineering Appendix (Appendix D) provides excavation quantities, a description of the plan to seed the reservoirs to develop ground cover, and a comprehensive list of equipment and hourly usage.

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2. Air Quality of the Lower Snake River

This chapter describes the affected regional air quality and meteorological environment of the lower Snake River. Federal and state air quality programs and the air quality standards that pertain to the Lower Snake River Juvenile Salmon Mitigation Feasibility Study are summarized in Section 2.1. Section 2.2 provides an overview of existing emission sources and air quality in the region. Section 2.3 addresses climatic factors that are relevant to the air quality analysis.

2.1 Air Quality Management

2.1.1 Regulated Air Pollutants

The Federal Clean Air Act (FCAA) requires the U.S. Environmental Protection Agency (EPA) to set ambient air quality standards to protect the public health and welfare. Standards to protect public health (primary standards) must provide for the most sensitive individuals and allow a margin of safety, without regard to the cost of achieving the standards. Secondary standards protect public welfare (crop damage, tire oxidation, etc.), rather than public health. Air quality standards have been established for carbon monoxide (CO), lead (Pb), particulate matter with aerodynamic diameters less than 10 micrometers (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and sulfur dioxide (SO_2).

Primary and secondary standards have been established for particulate matter that can be respired by humans. The original standards for total suspended particulate matter (TSP) were revised in 1987 when standards for PM_{10} were established. PM_{10} can penetrate deep into the respiratory tract and lead to a variety of respiratory problems and illnesses. A number of published studies suggest that premature mortality, hospital admissions, and respiratory illnesses occur at concentrations below the PM_{10} standards.

In 1997 EPA revised the particulate matter standards by adopting new standards for particles smaller than 2.5 micrometers ($PM_{2.5}$). EPA has retained the annual PM_{10} standard and adjusted the 24-hour standard until implementation strategies can be put into place. EPA is in the process of issuing new rules related to particulate matter monitoring requirements under the new standard, the establishment of nonattainment areas, and revising the New Source Review (NSR) process.

Although the Federal government stopped regulating large particles, several states maintained the TSP standards, in part to address nuisance dust problems. The Washington State Department of Ecology (Ecology) enforces a TSP and PM_{10} standard, and will adopt $PM_{2.5}$ standards, similar to the Federal standards of an annual average of 15 micrograms per cubic meter ($\mu g/m^3$) and a 24-hour average of 65 $\mu g/m^3$.

EPA also revised the ozone standard in 1997, provided guidance for implementation of the regional haze regulations, and provided for a transition period to the new standard. The ozone standard is expressed as a 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration, and is set at 0.08 parts per million (ppm). Ecology will retain the 1-hour 0.12 ppm standard until it adopts new regulations.

EPA has delegated several air quality regulatory responsibilities to state and local agencies. The state and local responsibilities include enforcing National and State Ambient Air Quality Standards

(AAQS), assuring human health protection from toxic air pollutants (TAPs), and mitigating nuisances caused by windblown dust. Standards for the State of Oregon Department of Environmental Quality (DEQ) are similar to the Washington standards. Applicable AAQS are found in Table 2-1.

Table 2-1. Ambient Air Quality Standards

Pollutant	National Primary	National Secondary	Idaho	Oregon	Washington
Proposed Fine Particulate Matter ($PM_{2.5}$) ($\mu g/m^3$)					
Annual arithmetic average	15	15			
24-hour average	65	65			
Fine Particulate Matter (PM_{10}) ($\mu g/m^3$)					
Annual arithmetic average	50	50	50	50	50
24-hour average 1/	150	150	150	150	150
Total Suspended Particulates (TSP) ($\mu g/m^3$)					
Annual geometric average				60	60
24-hour average 1/				150	150
Carbon Monoxide (ppm)					
8-hour average	9	9	9	9	9
1-hour average	35	35	35	35	35
Ozone (ppm)					
Proposed 8-hour average	0.08	0.08			
1-hour average 2/	0.12	0.12	0.12	0.12	0.12
Sulfur Dioxide (ppm)					
Annual average	0.03	0.02	0.03	0.02	0.02
24-hour average	0.14		0.14	0.10	0.10
3-hour average		0.50	0.50	0.50	
1-hour average 3/					0.25
1-hour average					0.40
Lead ($\mu g/m^3$)					
Calendar quarter average	1.5		1.5	1.5	1.5
Nitrogen Dioxide (ppm)					
Annual Average	0.053	0.053	0.053	0.053	0.05

Source: 40 CFR Part 50, IDAP 16.01.01.577, OAR 340-031, and WAC 173-470, -474, -475

Notes:

ppm = parts per million

($\mu g/m^3$) = micrograms per cubic meter

Annual standards never to be exceeded, shorter-term standards not to be exceeded more than once per year unless noted.

1/ Standard attained when expected number of days per year with a 24-hour concentration above 150 $\mu g/m^3$ is less than or equal to one.

2/ Standard attained when expected number of days per year with an hourly average above 0.12 ppm is less than or equal to one.

3/ Not to be exceeded more than twice in 2 days.

Ecology also regulates emissions from large combustion sources such as power plants. Atmospheric emissions of nitrogen oxides (NO_x) are regulated because they can convert to NO_2 and are ozone precursors. Volatile organic compound (VOC) emissions are also regulated because they are ozone precursors.

New major stationary sources and major modifications to existing sources are subject to more scrutiny during the construction permitting process, a process known as new source review (NSR). In general, a major stationary source has the potential to emit 90,720 kgs (100 tons) per year of any regulated air pollutant. A new fossil-fuel-fired steam electric plant is a major source. A major new source located in an area where monitoring indicates that ambient concentrations are lower than the AAQS (the area is in attainment) would be subject to prevention of significant deterioration (PSD) provisions. In this case, the applicant would do the following:

- Demonstrate that emissions are controlled with BACT.
- Demonstrate that emissions would not result in ambient concentrations greater than the AAQS.
- Determine if the emissions would impair visibility or impact soils and vegetation.
- Determine if the emissions would impair air-quality-related-values in PSD Class I areas within 100 km of the source.
- Undergo public participation.

Class I areas are designated for special protection and include national parks and wilderness areas. In California, Idaho, Oregon, and Washington there are 29, 5, 12, and 8 Class I areas, respectively (40 CFR 81.400). Sources located in nonattainment areas are subject to the provisions listed above and must offset their emissions. The Class I areas closest to the lower Snake River are as follows:

- The Hells Canyon Wilderness area, located 72 km (45 miles) south of Clarkston
- The Eagle Cap Wilderness area, located 140 km (87 miles) southwest of Clarkston and 142 km (89 miles) southeast of the Ice Harbor Dam.

Emission standards have been established for a number of source types. New electric utility steam generators and stationary natural gas-fired turbines must demonstrate that their emissions are lower than those specified in the New Source Performance Standards (NSPS, 40 CFR Part 60). Additional hazardous air pollutant emission standards have been proposed for combustion turbines.

Conformity refers to Section 110 of the FCAA, which stipulates that the control of emissions from one state will not significantly contribute to the attainment of an air quality standard in another state. For example, conformity will apply to federally funded transportation projects that may lead to air pollution problems in another state. For the emissions considered in this Appendix, conformity could apply to the following:

- Fugitive emissions from dry lake sediments that blow into Lewiston, Idaho
- Emissions from power plants proposed for locations in or near nonattainment areas
- Increased locomotive or truck emissions from vehicles that transport grain that would normally be shipped on the Snake River.

Local air pollution control programs for particulate matter include restrictions on woodsmoke, open burning, and industrial operations. Complaints of windblown dust are reported to local authorities, who will investigate potential mitigation measures and impacts to human health. Windblown dust is one component of fugitive emissions, which are emissions from sources other than industrial vents and stacks. Construction sites may suppress fugitive dust by water spraying. Large fugitive dust sources are difficult to limit because they are not localized, are subject to extreme changes in character with weather, and are generally not under human control. As such, mitigation measures may be extremely difficult to identify.

The standards for toxic air pollution vary by state. Ecology regulates emissions of individual TAPs (Washington Administrative Code [WAC] 173-460). Many HAPs and TAPs are VOCs. Ecology's rule is to protect the public from exposure to unhealthy levels of toxic and cancer-causing emissions from new industrial sources. Ecology's TAP list is more extensive than the EPA's HAP list.

The U.S. Environmental Protection Agency (EPA) regulates hazardous air pollutant (HAP) emissions through the National Emission Standard for Hazardous Air Pollutants (NESHAP). Combustion turbines are sources of small amounts of HAPs, particularly formaldehyde. Very large turbines, or groups of turbines, could emit individual HAPs in quantities greater than 9,072 kgs (10 tons) per year, or all HAPs in quantities greater than 22,680 kgs (25 tons) per year. As required by Title III of the FCAA, a NESHAP for combustion turbines is currently under development. The combustion turbine NESHAP will establish emission limits and control requirements, and will probably become effective within 10 years (see http://www.epa.gov/ttn/uatw/mactprop.html).

In May 1999, the U.S. Court of Appeals for the District of Columbia sent the $PM_{2.5}$ and O_3 standards back to EPA for further action and voided the PM_{10} standard. The courts reasoned that, because only a concentration equal to zero is risk-free, EPA must develop binding principles to justify setting a standard at a higher level, and the agency had not provided such a principle. The court held that EPA's choice of PM_{10} as an indicator of coarse particulate matter was arbitrary and capricious in light of its new $PM_{2.5}$ standard. PM_{10} would cover fine particles regulated by $PM_{2.5}$. The agency failed to justify its decision not to regulate particles in the range between $PM_{2.5}$ and PM_{10}. EPA has filed a petition for a rehearing. The issue will probably be reviewed by the entire court. The timeline for implementation of the regional haze rule is tied to the schedule for implementation of the $PM_{2.5}$ standard.

2.1.2 Greenhouse Gases

Over the past 100 years, carbon dioxide levels in the atmosphere increased by about 25 percent. Carbon dioxide concentrations will continue to increase as the world population grows and societies around the globe industrialize. The dynamics of the atmosphere, and thus the climate of the earth, are affected by changes in the ability of the atmosphere to retain heat. Heat retention is enhanced by increased concentrations of GHGs.

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization and the United Nations Environment Programme in 1988 to assess the available scientific, technical, and socioeconomic information regarding climate change. A 1996 IPCC report concluded that:

> Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability,

> and because there are uncertainties in key factors. These include the magnitudes and patterns of long-term variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate (IPCC, 1996).

The text of the Framework Convention on Climate Change (FCCC) was adopted by the United Nations and opened for signature at Rio de Janeiro in 1992. At Rio de Janeiro the world's industrialized nations agreed to establish policies and measures that reduce emissions of the GHGs. The FCCC was signed by 150 nations including the United States. To meet this pledge, President Clinton unveiled the United States Climate Change Action Plan (CCAP) in October 1993. Its main goal is to reduce United States GHG emissions to their 1990 levels by 2000. In 1997, representatives from more than 160 countries met in Kyoto, Japan, to negotiate binding limits on GHG emissions for developed nations. The target for the United States is 7 percent below 1990 levels (Energy Information Administration, 1998). Although global climate is influenced by GHG concentrations, the Protocol establishes targets in terms of annual emissions. GHCs addressed by the Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFC), partially halogenated fluorocarbons (HCFC), and ozone.

Under the CCAP, states play a critical role in reducing GHG emissions. EPA's State and Local Climate Change Outreach Program partners with states to create GHG inventories and action plans for individual states. Washington State's Action Plan sets the goal to stabilize GHG emissions through an 18-million-ton reduction from "business as usual" by 2010. In order to meet this goal, the GHG emissions associated with each proposed project should be analyzed for their impact on the State GHG inventory.

A GHG inventory is a prerequisite for evaluating the cost effectiveness and feasibility of mitigation strategies and reduction technologies. The air quality analysis in this appendix evaluates emissions from thermal power plants. This discussion will focus on CO_2, the principal GHG resulting from fossil fuel combustion. Table 2-2 shows EPA's annual GHG inventory lists 1997 CO_2 emissions for the following categories (EPA, 1999).

Table 2-2. 1997 CO_2 Emissions, by Category

Source	Millions of Tons
Fossil fuel combustion	5,925.3
Other	931.6
Land-use change and sinks	(843.1)
Total	**6,013.8**

Emissions of CO_2 from fossil fuel combustion include about 1,952 million metric tons (2,152 million tons) from the electric utility industry. Nationally natural gas combustion accounts for 1,955 million metric tons (2,156 million tons) of CO_2 emissions. CO_2 emissions from fossil fuel combustion may be further subdivided into the sources shown in Table 2-3.

Table 2-3. CO_2 Emissions from Fossil Fuel, by Subcategory

Source	Millions of Tons
Residential	1,156.4
Commercial	958.3
Industrial	1,955.0
Transportation	1,804.7
U.S. Territories	50.9
Total	**5,925.3**

2.2 Overview of Existing Air Quality

Industrial operations, woodsmoke, road dust, and windblown dust from disturbed surfaces (such as agricultural fields) are the primary sources of fugitive dust in the atmosphere. All of these sources are present in the lower Snake River region. Industrial emissions are the primary source of gaseous criteria air pollutants, TAPs, and GHGs.

2.2.1 Sources of Air Emissions

The air quality in the lower Snake River region generally continues to meet the AAQS. Components of the air quality environment include emission sources, ambient air pollutant concentrations as measured by a sampling network, and meteorological effects that govern the generation of windblown dust and the behavior of emitted industrial emissions. These influences are discussed below.

Particulate sources within the basin include area sources (dirt or gravel roads and plowed fields) and industrial point sources (manufacturing plants). Area sources are subject to wind erosion that results in blowing dust. Typical manufacturing plant emissions include soot and fine wood particles. Throughout the arid and semi-arid portions of eastern Washington, wind erosion is the primary cause of dust emissions, often associated with dryland farming. Wind-blown emissions are also produced by irrigated agriculture and nonagricultural sources such as exposed reservoir shorelines.

Similar conditions for particulate emissions apply to the Feasibility Study area. The Reclamation EIS (Bureau of Reclamation, 1989) reported the following characterization for eastern Washington:

> Area sources are far more important than point sources because of the prevalence of wind erosion. Wind erosion is greatest during the spring and fall, when high winds and dry soil conditions create dust storms of varying severity. Highway and road closings are sometimes necessary because of reduced visibility. The severity of dust storms is exacerbated by dryland agricultural practices, which expose the soil during spring cultivation and fall harvesting.
>
> Annual total suspended particulate readings at Pasco, Washington (based on a 12-month moving geometric mean concentration) ranged from 45 to 65 $\mu g/m^3$ during the mid-1980s and in some years exceeded the Washington State annual standard of 60 $\mu g/m^3$. Over the same period, there were from 2 to 4 days per year on which particulate concentrations exceeded the 150 $\mu g/m^3$ standard for a 24-hour period.

The above conditions and measurements apply specifically to eastern Washington agricultural areas. Extensive agricultural areas around or near the lower Snake River reservoirs will contribute to PM_{10} concentrations in the Snake River canyon, where there is limited disturbed land. PM_{10} concentrations along the river are likely smaller than the agricultural and industrial areas.

Thermal power plants commonly emit CO, CO_2, NO_x, particulate matter (PM), and SO_2 as combustion by-products. Air quality is a particular concern around these generating plants, and more stringent emission controls are required for existing facilities and new projects in these affected areas. All recent additions to Northwest thermal plant capacity have been natural gas-fired combined-cycle combustion turbines. These plants use the least-polluting carbon fuel in highly efficient engines, in which chemical emissions can be effectively controlled.

2.2.2 Major Industrial Sources of Air Emissions

Major industrial emission sources (emission rates greater than 90,720 kgs (100 tons) per year [TPY]) within 50 km (31 miles) of the four lower Snake River dams are located in Benton, Franklin, Walla Walla, and Whitman counties. Table 2-4 lists emissions data for local major sources (sources which emit less than 90,720 kgs (100 tons) of a pollutant are not reported) in these counties, for the most recent reporting year available (EPA, 1998a).

Table 2-4. Major Air Emission Sources within the Region of the Lower Snake River

	Source			Emissions			
County	City	Facility	Units	NO_2	PM_1	SO_2	VOC
Benton, WA	Plymouth	Northwest Pipeline	TPY	192			
	Benton City	A & B Asphalt	TPY		177		
	Kennewick	Harvest States Corp	TPY		126		
	Richland	Acme Materials Construction	TPY		104		
Franklin, WA	Pasco	Tidewater Terminal	TPY				1,427
	Pasco	Chevron Northeast Terminal	TPY				215
Walla Walla, WA	Starbucks	Pacific Gas Transmission	TPY	330			
	Wallula	Pacific Gas Transmission	TPY	326			
	Walla Walla	Crown Cork & Seal	TPY				297
Whitman, WA	Pullman	Washington State University	TPY	240		121	
Lath, ID	Moscow	Potlatch Corp	TPY	133			

Source: EPA, 1998a.
metric tons per year (MTY) = TPY * 0.907
TPY = Tons per year

Collocated $PM_{2.5}$ and PM_{10} monitoring provides an opportunity to compare the composition of the particles (EPA, 1997a). Although collected in other parts of the United States (Arizona, California, Colorado, South Dakota, and other southern and eastern states), the monitoring data are generally representative of the arid environment of the lower Snake River region. $PM_{2.5}$ is composed of particles emitted directly into the air and particles formed in the air from chemical transformation of gaseous pollutants (secondary particles). The principal types of secondary particles are created from the reaction of SO_2 and NO_x emissions with ammonia (NH_3). The principal types of directly emitted particles are soil particles and organic or elemental carbon particles from fossil fuel combustion and biomass materials. The soil particle component is low for $PM_{2.5}$ (5 to 15 percent, versus about 50

percent for PM_{10}), but the combustion component is much higher (35 to 60 percent, versus about 15 to 23 percent for PM_{10}). The fraction of nitrates and sulfates in $PM_{2.5}$ is about 13 and 24 percent, respectively.

2.3 Existing Air Quality

2.3.1 Ambient Air Pollutant Concentrations

Although Benton, Franklin, and Whitman counties achieve all state and national AAQS with respect to industrial emissions, wind blown fugitive dust continues to be a problem. The second highest 24-hour and annual average PM_{10} concentrations for 1997 are presented in Table 2-5. The monitoring stations are located close to major air emissions sources. There are few industrial sources in the areas of the four dams and little agricultural land immediately adjacent to the Snake River that is regularly disturbed. Therefore, the monitoring data are not representative of air quality at the project locations or at the large agricultural areas subject to wind erosion. With few industrial sources, wind blown fugitive dust is the only pollutant of concern for the region.

Land use in the area of the lower Snake River is primarily agricultural. From September to November, irrigated and fallow soils are bare and dry, dry harvested fields contain some vegetative residue, and rangelands are dry. Background PM_{10} concentrations during these periods are typically 20 to 40 $\mu g/m^3$. The area is susceptible to erosion during periods of high wind speeds. High wind speeds result in large particulate matter emissions and elevated PM_{10} concentrations along the storm tracks. Monitoring and modeling studies associated with the Columbia Plateau PM_{10} Program (see below) indicate that the largest particulate matter emissions and associated concentrations occur in the area from Kennewick to Spokane, and may include the area of the Ice Harbor and Lower Monumental dams.

Table 2-5. Regional Ambient Air Pollutant Concentrations

	PM_{10} Concentration ($\mu g/m^3$)	
Station	**Second Highest 24-hour**	**Annual Average**
Kennewick	77	20.4
Walla Walla #1	105	31.8
Walla Walla #2	160	12.6
Clarkston	122	37.3
Lewiston #1	63	29.7
Lewiston #2	66	27.4
Spokane #1	79	25.2
Spokane #2	48	28.8
Spokane #3	77	29.6

Source: EPA, 1998a.

The locations where measured pollutant concentrations are greater than the AAQS are referred to as nonattainment areas. All nonattainment areas are outside the study area. One PM_{10} nonattainment area lies relatively close to the western end of the lower Snake River. Other PM_{10} nonattainment areas are relatively distant:

- The Wallula nonattainment area is about 18 km (11 miles) south of the Ice Harbor Dam.

- The Pendleton nonattainment area is located about 60 km (38 miles) south of the Ice Harbor Dam.
- The Spokane nonattainment area is about 103 km (50 miles) north of the Lower Granite Dam.
- The proposed Kootenai County nonattainment area is located about 115 km (79 miles) north of Clarkston/Lewiston and the eastern end of the Lower Granite reservoir.

The air quality problem associated with the Wallula nonattainment area appears to be related to industrial emissions and fugitive dust. The other nonattainment areas have problems associated with blowing dust and agricultural practices.

2.3.2 Recent Windblown Dust Studies

Several studies have investigated problems associated with blowing dust. The Northwest Columbia Plateau Wind Erosion Air Quality Project (WEAQP) is a cooperative project that seeks to quantify wind erosion on agricultural lands in eastern Washington. The Great Basin Unified Air Pollution Control District studied wind erosion control methods as part of the Owens Valley, California, PM_{10} demonstration of attainment. The Lake Koocanusa Fugitive Dust Study measured PM_{10} concentrations associated with seasonal blowing dust from a western Montana lake bed. The results of these studies are summarized below.

2.3.2.1 The Columbia Plateau Wind Erosion Air Quality Project

The Columbia Plateau PM_{10} Program (CP^3) is a multi-investigator study of wind erosion and windblown dust in area of the eastern Washington, northeast Oregon, and the Idaho panhandle, with an emphasis on the role of agricultural lands and regional dust storms. Typical 24-hour background PM_{10} concentrations are about 34 $\mu g/m^3$ in the early fall and 10 $\mu g/m^3$ in the late fall. During wind events ambient concentrations at urban receptors can exceed 500 $\mu g/m^3$ on an hourly basis and 300 $\mu g/m^3$ in 24 hours. The abbreviated objectives of the CP^3 include (WEAQP, 1995):

- Develop a database of climate, soil, vegetation, and farming practices required to estimate PM_{10} emissions.
- Establish the theory, quantification, and verification of wind erosion on agricultural lands, using instrumented field sites and a portable wind tunnel.
- Develop a PM_{10} emissions inventory and probable urban impacts.
- Obtain, test, and evaluate air transport-dispersion-deposition model suitable to predict PM_{10} concentrations from agricultural emissions sources.
- Identify and test wind erosion and PM_{10} emission control methods and evaluate their effectiveness.
- Appropriately reclassify highly erodible lands for control and develop a strategy to set on-farm compliance and assistance.
- Determine the relative impact of human activity on suspended dust and PM_{10} emission rates by determining erosion rates for non-anthropogenic and anthropogenic areas.
- Develop an awareness and increased understanding about wind erosion, PM_{10} emissions, and current and prospective control methods.

- Increase understanding of the health impacts of particulate air pollution.
- Develop agricultural windblown dust best-management practices and implementation policies.
- Develop a particulate air quality plan to achieve solutions to PM_{10} problems throughout the Columbia Plateau.

The most severe windblown dust events occur during the relatively dry September to mid-November period. However, dust storms can occur during the spring and summer. Dust storms are characterized by a surface low pressure system located in southern British Columbia or Alberta and a surface high pressure system in the southwest United States. The southwest winds generated by the low pressure system are enhanced by the clockwise flow around the high pressure system. Storms moving through eastern Washington toward the Northeast may impact an area from Kennewick to Spokane, which includes the western area of the lower Snake River. Storms that generate fugitive dust in the western region of the lower Snake River may miss the eastern reach of the river. Other storms may impact the Pendleton to Clarkston/Lewiston area.

The CP^3 program investigated several storms that struck the area between 1990 and 1993. Field measurements during two major dust storms during the fall of 1993 measured maximum 24-hour PM_{10} concentrations equal to 300, 255, and 1,166 of $\mu g/m^3$ at an industrial site in Spokane, a residential site in Spokane, and an urban site in Kennewick, respectively. A regional windblown PM_{10} emissions-dispersion-deposition model was calibrated with data from a portable wind tunnel. The model reasonably reproduced the measured concentrations from the fall of 1993, and was used to predict PM_{10} concentrations throughout the Columbia Plateau (Claiborn et al., 1998).

During the 11 September 1993 wind storm, peak wind speeds were 12.2 m/sec (5.45 mph) and measured 24-hour PM_{10} concentrations exceeded 200 $\mu g/m^3$ in Spokane and 100 $\mu g/m^3$ in Kennewick. The highest hourly concentration was over 2,000 $\mu g/m^3$. Total emissions from dry agriculture lands, irrigated agricultural lands, and rangelands for this wind storm are estimated at 116 million metric tons (128 million tons). The emission source was near Kennewick, and the plume stretched to the northeast. During the 3 November 1993 event the winds reached 26 m/sec (58 mph). The highest measured 24-hour concentrations in Adams County reached 187 $\mu g/m^3$, and the highest measured 1-hour concentration is Spokane was 440 $\mu g/m^3$. Total emissions from dry agriculture lands, irrigated agricultural lands, and rangelands are estimated at 81 million metric tons (89 million tons). During both of these events predicted 24-hour PM_{10} concentrations near the Ice Harbor and Lower Granite reservoirs were 2,400 and 50 $\mu g/m^3$, respectively.

2.3.2.2 The Owens Valley PM_{10} Demonstration of Attainment

The Owens Valley MP_{10} Demonstration of Attainment provided useful information. Owens Lake, located in eastern central California, is the source of large amounts of dust. The southern portion of the Owens Valley is a "serious" PM_{10} non-attainment area. The designation is "serious" because of frequent violations of the national AAQS and an inability of the area to attain the standards by 31 December 1995. Emissions from Owens Lake has been predicted to cause exceedances of the 24-hour AAQS up to 31 km (50 miles) away. The Great Basin United Air Pollution Control District published an attainment plan in 1998, which includes ambient meteorological and PM_{10} measurements, dust emission measurements, and the effectiveness of several control strategies.

Winds exceeding 18 m/sec (40 mph) are associated with passing storm systems. As storm systems approaches the Owens Valley, strong southerly winds switch to strong northerly winds with passage of the front. Data from a monitoring network indicates that PM_{10} concentrations in communities adjacent or near the dry lake frequently exceed the AAQS. The peak 24-hour concentrations and the expected number of exceedances per year, derived from about 9 years of sampling, are show in Table 2-6.

Table 2-6. Peak 24-hour Concentrations and the Expected Number of Exceedances Per Year near Owens Lake, California

Location	Direction from Owens Lake	Peak 24-hour PM_{10} Concentration ($\mu g/m^3$)	24-Hour Average Wind Speed (m/sec)	Date of Peak Concentration	Expected Number of Exceedances Per Year
Keeler	East	3,929	14.6	4/13/1995	19
Lone Pine	North	499	10.7	3/18/1994	2
Olancha	South	2,252	13.0	4/9/1995	5

Source: Great Basin Unified Air Pollution Control District, 1998.

Owens Lake and secondary sources (wind borne deposits of Owens Lake material) comprise 99.99 percent of the PM_{10} emissions inventory of Inyo County. Wind tunnel measurements, sun photometry (measuring changes in scattered sunlight) and field mapping of eroded areas were used to estimate annual PM_{10} emissions of between 118,000 and 382,000 MTY (130,000 and 420,000 TPY). Lake Owens dust also contains arsenic and cadmium at concentrations that result in life-time cancer risks of 18 per million and 6 per million, respectively. The cancer risk values are based on the 9 year average PM_{10} concentration of 50 $\mu g/m^3$.

Several emission control strategies have been tested at Owens Lake. The testing included estimating the effectiveness at reducing PM_{10} emissions. The proposed Control strategies are shown in Table 2-7.

Table 2-7. Effectiveness of Emission Control Strategies

Control Method	Emissions Reduction (Percent)	Coverage
Shallow flooding	99	75 percent of emitting area between September and June
Managed vegetation	99	50 percent plant coverage on 75 percent of the managed area
Gravel cover	100	100 percent

Source: Great Basin Unified Air Pollution Control District, 1998.

Shallow flooding will mimic the physical and chemical processes of natural springs and wetlands on the relatively flat Owens Lake playa. Winter and spring flooding are effective in reducing emissions because summer wind events are rare. The salt-affected soils of Owens Lake must first be reclaimed before salt-tolerant plants, such as saltgrass, can be planted. The gravel cover consists of a 101.6-mm (4-inch) layer of gravel greater than 9.5 mm (3/8 of an inch) in diameter. The gravel cover increases the threshold velocity required to move surface particles. To remain effective, the gravel cover must not become covered with dust.

2.3.2.3 The Lake Koocanusa Fugitive Dust Study

A recent similar study has illuminated the meteorological conditions associated with high fugitive dust events (Environalysis, 1996). PM_{10} monitoring was conducted at Lake Koocanusa, the reservoir formed by Libby Dam on the Kootenai River in northwestern Montana. Lake Koocanusa refills with snowpack melt in the late spring and summer. Two years of monitoring (May 1994 through June 1996) included meteorological conditions, continuous PM_{10} concentrations at the lake and in the nearby town of Eureka, and passive dust settling measurements. The following meteorological conditions are associated with entrainment of fugitive dust:

- High dust events are preceded by several hours of increasing wind speeds from a constant direction.
- The wind speeds that initiate a dust event are not unusually high. A minimum threshold of wind energy is required to initiate the dust event.
- The high wind events last up to 9 hours.
- Background levels may significantly contribute to the measured concentrations.
- Dust levels rapidly fall when the wind speed drops below about 5 meters per second (m/sec) (10 miles per hour [mph]).
- Dry lake banks appear to provide turbulent conditions that enhance emissions and produce more emissions.

The geography and micro-topography of the dry lakebed sediments can be an important factor. Different wind patterns can affect different areas of the lakebed. Steep slopes, which allow heavier particles to roll downslope, make smaller particles available for entrainment. Although some 1-hour PM_{10} concentrations measured during the Lake Koocanusa study were very large, all 24-hour concentrations were less than the air quality standard.

On several occasions measured maximum 1-hour PM_{10} concentrations exceeded about 500 $\mu g/m^3$. In all cases the average 24-hour PM_{10} concentrations were below 100 $\mu g/m^3$, or about 67 percent of the AAQS. The dust events were characterized by moderate persistent winds and dry conditions, and lasted from between 3 and 9 hours. The largest measured 1-hour concentration was associated with winds that blew over large areas of exposed lake banks.

2.4 Climatic Factors

Dry, loose lake sediments become airborne during high wind events. Surface particles are much less mobile if the ground is wet or frozen. The greatest potential for windblown dust coincides with periods of low relative humidity, extended sunshine, and warm to hot temperatures. The wind, precipitation, and temperature conditions of the lower Snake River region are discussed below. Monthly tabulations of climatic variables are presented in Annex A.

2.4.1 Precipitation and Temperature

The availability of soils that may be subject to wind erosion is partially a function of the precipitation and temperature climatology of the region. Moisture will help hold soil particles together and reduce erosion potential. Higher temperatures enhance evaporation, drying soils, and

providing particulate matter that may be subject to wind erosion. Soil erosion is negligible when the temperatures are below freezing.

The Cascade Mountains effectively block most of the precipitation from entering southeast Washington. Annual precipitation amounts are about 250 millimeters (mm) (10 inches) or less, with most of the precipitation falling during the winter as snow (Figure 2-1) (Corps, 1999). Some locations in southeast Washington and northeast Oregon experience only small amounts of summer rain. Relative humidity values can fall to 10 percent or less on hot summer afternoons. Precipitation amounts generally increase with elevation, and are slightly higher in the Clarkston and Lewiston area.

Climatic conditions in the lower Snake River area are characterized by large seasonal temperature differences, low precipitation, and relatively minimal cloud cover. Valley bottoms along the Snake River record some of the highest summer temperatures in the region, and they tend to stay slightly warmer than surrounding upland areas in the winter.

Precipitation is typically concentrated in the late fall, winter, and early spring, with more arid conditions prevailing from late spring through the summer. Precipitation reduces the availability of particulate matter susceptible to erosion during high wind speed conditions. The reservoirs on the middle and lower Snake River generally experience measurable precipitation on 90 to 120 days per year (Jackson and Kimerling, 1993).

Long-term precipitation and temperature data are available for Ice Harbor Dam, which is representative of the western Snake River area. Precipitation and temperature data from Lewiston, located about 40 km (25 miles) southeast of the Lower Granite Dam, are representative of the eastern area of the lower Snake River. In general, normal precipitation amounts increase and temperatures decrease from west to east across the lower Snake River area (Figures 2-2 and 2-3). Figures 2-2 and 2-3 are based on more than 30 years of data (NOAA 1999 a and b).

2.4.2 Wind Conditions

Air quality at specific locations within the basin is heavily influenced by wind conditions, which in turn reflect both prevailing regional patterns and local topographic factors. The prevailing wind direction in southeastern Washington is from the southwest in both winter and summer. Average wind speeds throughout the basin are generally in the range of 11 to 13 kilometers per hour (km/hour) (7 to 8 mph). Some locations have considerably higher wind speeds (Jackson and Kimerling, 1993).

Infrequent July and August thunderstorms, which usually drop only small amounts of rain, are sometimes accompanied by strong wind gusts. Winter weather conditions in the region often produce strong winds flowing across the region. Local winds in the reservoir areas are often channeled parallel to the shoreline by the river valleys. Local topography can also act as a funnel that increases wind speeds. A daily cycle of changing up-valley and down-valley local wind directions can be common, particularly in mountain areas.

Long-term wind speed and wind direction data are available for only a limited number of stations, all of which are located outside the lower Snake River area. The three closest stations are Pendleton, Oregon, and Spokane and Yakima, Washington.

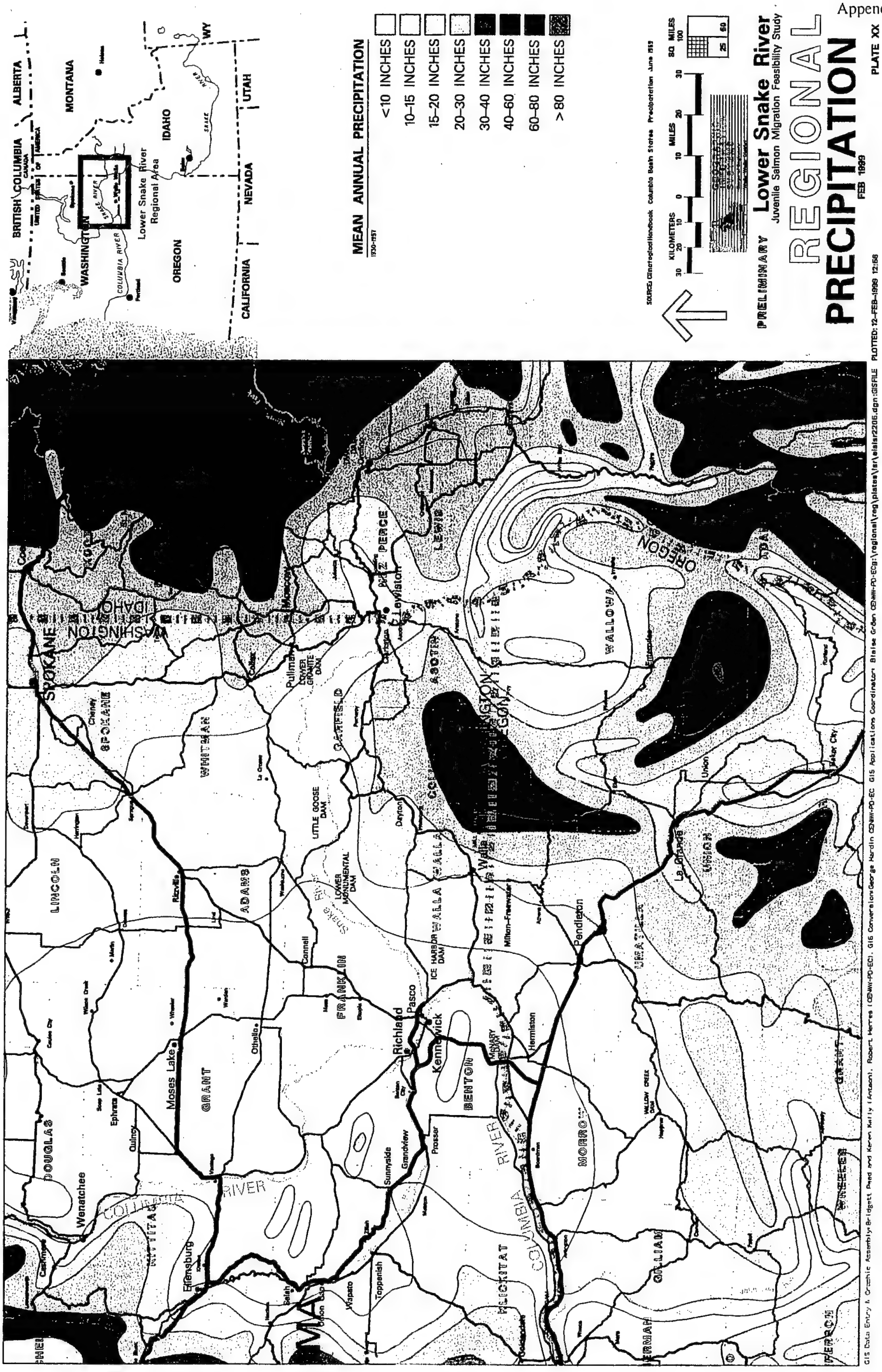

Figure 2-1. Regional Precipitation

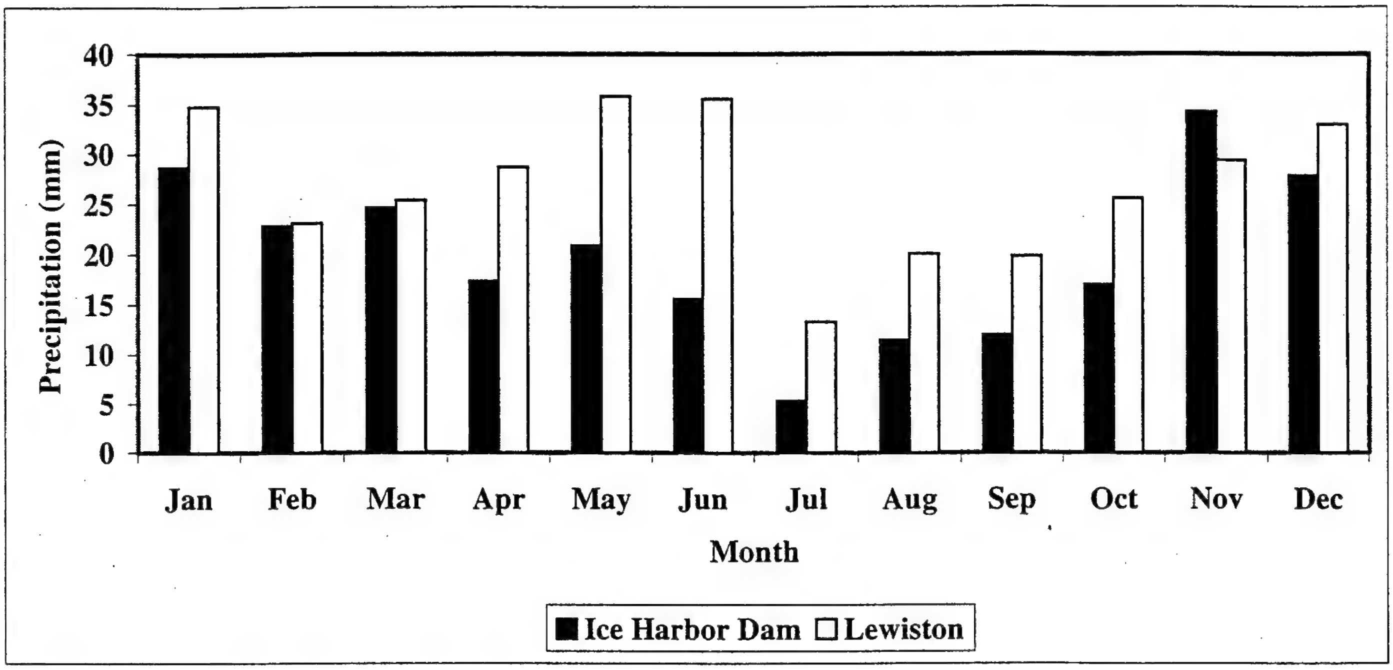

Figure 2-2. Average Monthly Precipitation Totals
Source: NOAA, 1999a

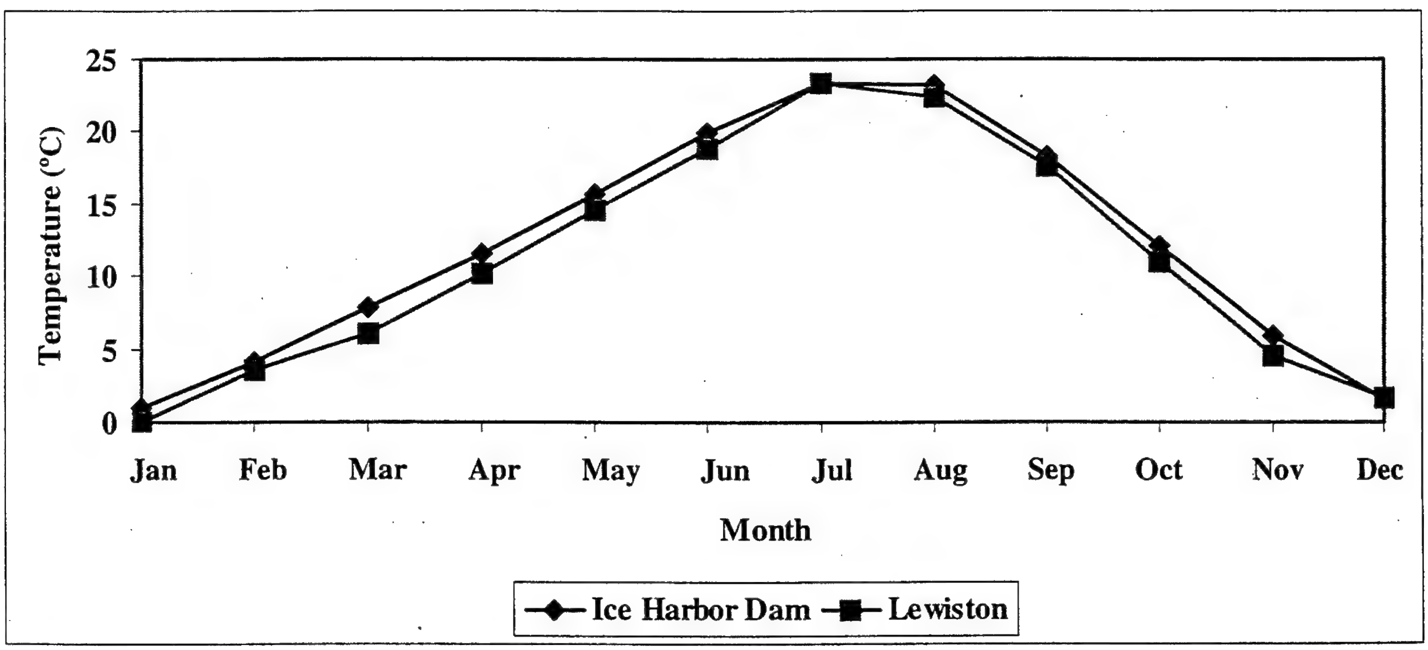

Figure 2-3. Average Monthly Temperatures
Source: NOAA, 1999b

Annual wind distributions are presented in Figures 2-4 through 2-6 as wind rose figures for the Pendleton, Spokane, and Yakima monitoring stations. A wind rose figure depicts the joint frequency of occurrence, in percentage, of wind speed and wind direction categories for a particular location and time period. The radials of the wind rose indicate the direction from which the wind is blowing. The length of the radials indicates the frequency of occurrence for that direction, and the width of the radials indicates the wind speed class. The wind rose figures are for the 8-year period between 1984 and 1991.

Table 2-8 lists primary wind directions, average wind speeds, and peak gusts for selected local meteorological monitoring stations. These average and peak gust speeds are relatively high, leading to a significant potential for windblown dust, if soil or sediments are exposed. Much of the interior plateau area near the Columbia and Snake rivers is dominated by fine-grained loessal soils that are particularly susceptible to wind erosion (Jackson and Kimerling, 1993).

Dry lake sediments are subject to erosion when the 1-hour average wind speeds reach 7.5 m/sec (16.7 mph), and the ground is not wet or frozen. Larger emissions are expected with higher sustained speeds. The data used to generate the wind rose figures were scanned to determine how often high wind speeds may be expected. The percent of time when 1-hour average wind speeds are greater than 7 and 10 m/sec, for the three monitoring stations, is as follows:

Percent of Hours Winds are Greater Than	Pendleton	Spokane	Yakima
7 m/sec (15.7 mph)	6	13	7
10 m/sec (22.4 mph)	1	2	1

Dust storms in eastern Washington are most common from September through November (Claiborn et al., 1998). The meteorological data indicate that, on average, there are about 10 high-wind-speed events of varying intensity per year from September through November.

Air quality concerns regarding industrial emission sources such as power plants pertain to different meteorological conditions. Maximum air pollutant concentrations resulting from stacks and combustion sources are a consequence of low wind speeds and very stable atmospheric conditions. Once a plume is emitted from a stack, the final height is a function of the effects of momentum and buoyancy. Greater plume rise is usually achieved with colder ambient temperatures.

Table 2-8. Wind Directions and Speeds for Selected Monitoring Stations

Variable		Units	Location		
			Pendleton	Spokane	Yakima
Average	Direction		W	SW	W
	Speed	m/sec	3.7	3.9	3.2
		mph	8.3	8.8	7.1
Peak Gust	Direction		SW	SW	NE
	Speed	m/sec	34.0	27.7	30.8
		mph	76	62	69
Fastest Mile	Direction		W	SW	W
	Speed	m/sec	34.4	26.4	21.5
		mph	77	59	48

Source: NOAA, 1990a, b, c, 1997a, b, c.

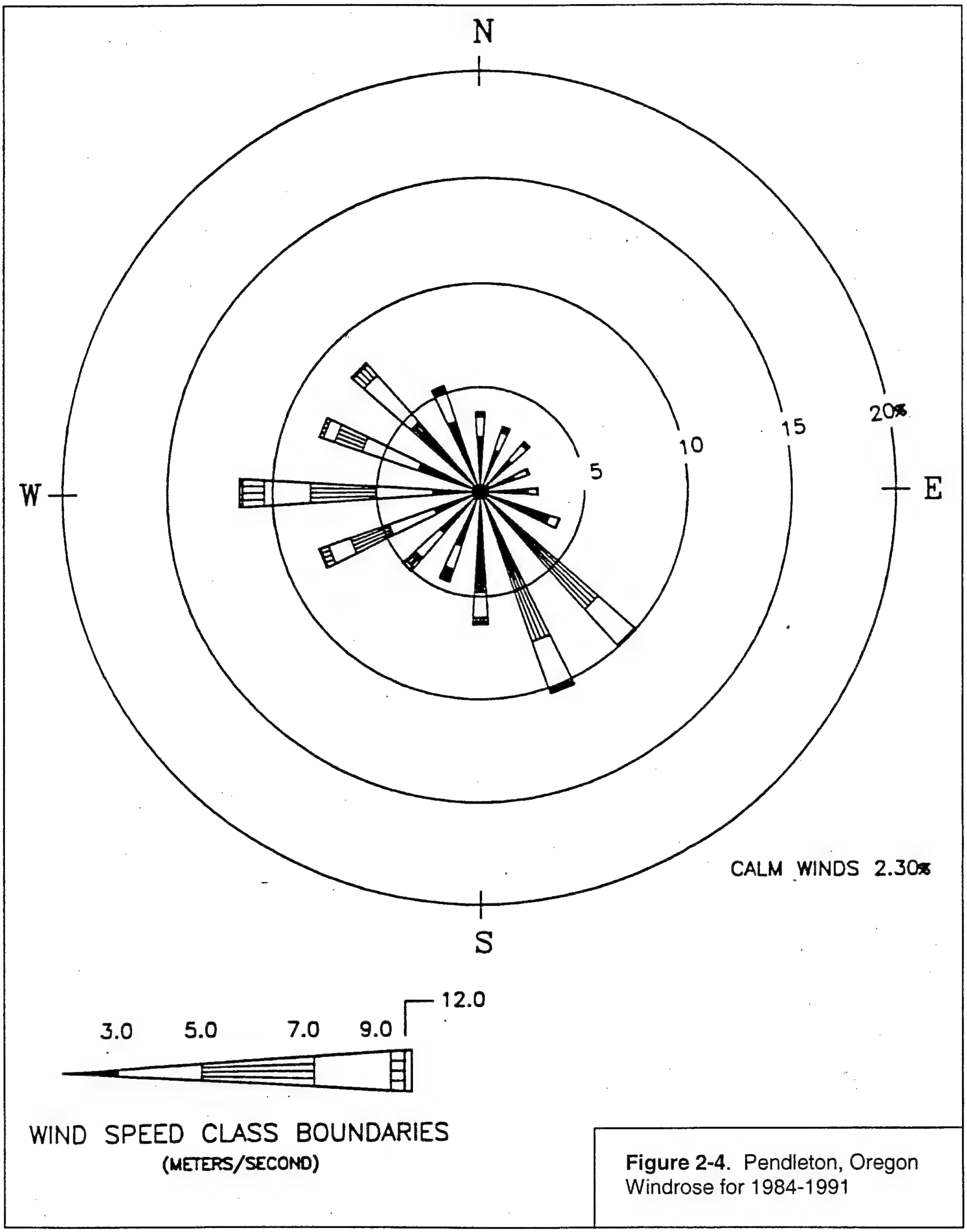

Figure 2-4. Pendleton, Oregon Windrose for 1984-1991

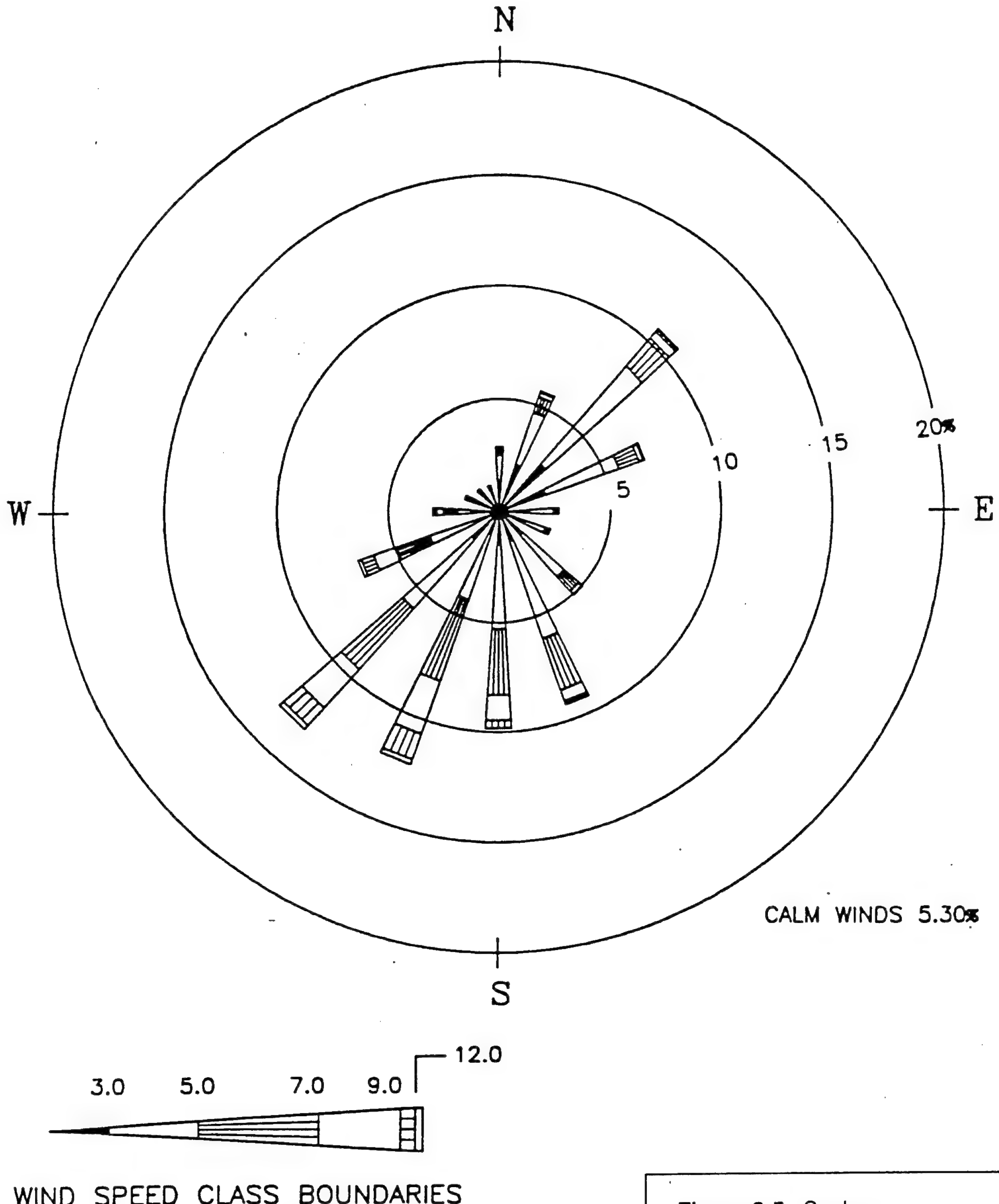

Figure 2-5. Spokane, Washington Windrose for 1984-1991

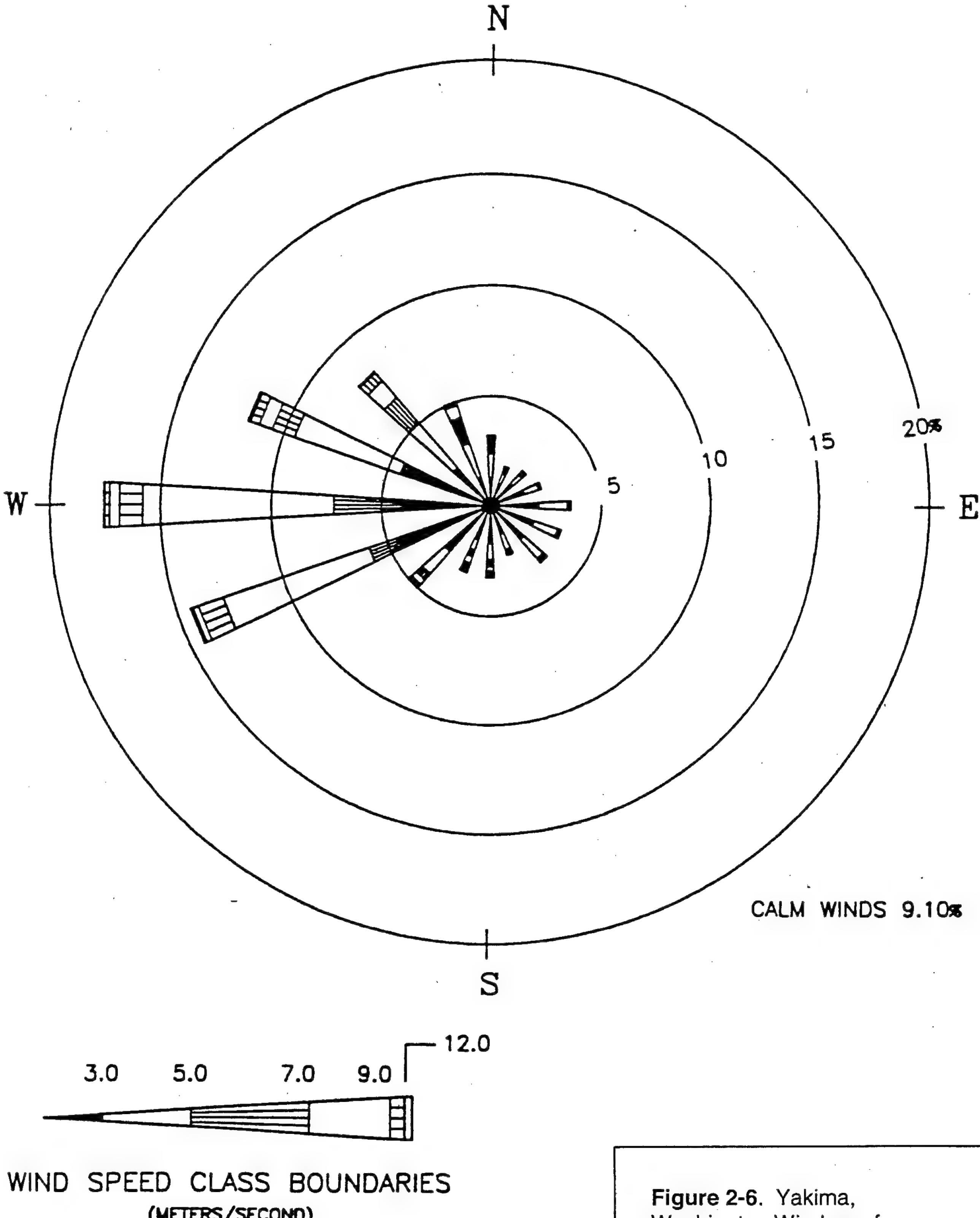

Figure 2-6. Yakima, Washington Windrose for 1984-1991

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3. Study Methods

Section 3 presents the methods used in this analysis of the air quality impacts associated with the Feasibility Study alternatives. This analysis addresses the four impact issues identified in Section 1:

- Fugitive dust emissions resulting from demolition of the dams
- The change in transportation-related emissions
- Nuisance effects of fugitive dust; and
- Emissions associated with replacement of hydropower.

The Natural River Drawdown Pathway would breach or remove the lower Snake River dams. Demolition activities such as hauling and dumping fill material would generate fugitive emissions. Section 3.1 presents methods used to estimate construction-related fugitive emissions.

Between 27.2 million and 36.3 million kgs (3 and 4 million tons) of freight pass through Ice Harbor Dam every year. Towboats emit pollutants from the confluence of the Columbia and Snake rivers to Lewiston, Idaho. The Natural River Drawdown Pathway would require a transfer of river freight to rails and roads, changing the amount and distribution of traffic-related air emissions. Section 3.2 presents the methods used to estimate the change in transportation-related emissions.

Wind-generated dust originating from dry reservoir sediments could be a problem in areas adjacent to the reservoirs. Limited monitoring data are available to characterize emissions from dry lake beds. As an alternative, a method for predicting the amount of particulate matter (PM_{10}) emitted during high wind speed events is presented (Section 3.3).

The Natural River Drawdown Pathway would require replacement of hydropower through increased power generation from existing plants or construction of new power generating capacity. Replacement of hydropower would increase atmospheric emissions of criteria air pollutants, HAPs, and GHGs. Section 3.4 presents the methods used to estimate emissions associated with replacement hydropower.

3.1 Demolition Fugitive Emissions

In terms of atmospheric emissions, excavation and deconstruction of the lower Snake River dams would be equivalent to a large construction project. Deconstruction could last a number of years, depending on the project schedule and whether one or more dams are demolished at one time. This analysis assumes that all four projects are demolished in two years. The principal construction operations that generate fugitive dust include unloading material from trucks and hauling, bulldozing, and grading the material. It is assumed that blasting would not be required. Deconstruction activities are generalized into bulldozing, batch dropping, hauling on unpaved roads, and grading.

Equations for construction-related emission factors are available from EPA (1998b). The emission factor equations are based on material handling rates, soil moisture content, silt content, and other factors such as vehicle weight and wind speed. The expressions include dimensionless multipliers to account for aerodynamic particle size. For this study, multipliers for PM_{10} have been incorporated into the equations. The equations also include the mitigative effects of rain. The

emission factor expressions used in this study are presented in Table 3-1. Bulldozer emissions are expressed in units of kilograms per hour (kg/hour). Hauling and grading emission factors are expressed in terms of vehicle kilometers traveled (VKT). Dropping emission factors are in terms of the amount of material, in metric tons (MT).

Table 3-1. Fugitive Dust Emission Equations

Operation	EPA, 1998b Reference	Units	Equation
Bulldozing	Table 11.9-2	kg/hour	$EF_B = 0.75 * (0.45 * s^{1.5} / M^{1.4}) * (365\text{-}p)/365$
Hauling	Section 13.2.2	g/VKT	$EF_H = 281.9 * (2.6 * (s/12)^{0.8}(W/3)^{0.4}) / (M/0.2)^{0.3} * (365\text{-}p)/365$
Dropping	Section 13.2.4	kg/MT	$EF_D = 0.35 * 0.0016 * (u/2.2)^{1.3} / (M/2)^{1.4} * (365\text{-}p)/365$
Grading	Table 11.9-2	kg/VKT	$EF_G = 0.60 * 0.0056 * S^{2.0} * (365\text{-}p)/365$

Where:
M = moisture content, in percent
p = number of days with measurable precipitation
s = silt content, in percent
S = mean vehicle speed, in km/hour
u = mean wind speed, in m/sec
W = mean vehicle weight, in metric tons.

Source: EPA, 1998b.

Annual fugitive emissions of PM_{10} are estimated for bulldozing, loading, hauling, dumping, and grading operations for each project, based on the amount of soil and fill material that must be moved to breach the dams. The emission calculations require volume of material, road lengths, and average weight of the haul trucks. The analysis does not include vehicle tailpipe emissions or emissions from worker camps. The default values for constants used in the emission calculations are presented in Table 3-2.

Table 3-2. Default Values for Emission Calculations

Constant	Symbol	Metric Value	Metric Unit	English Value	English Unit	Reference
Average grader speed	S	11	kph	7	mph	EPA, 1998b
Average trip duration		0.5	hours	0.5	hours	
Average trip length		12.1	km	7.5	miles	
Average truck speed		24.1	kph	15.0	mph	EPA, 1998b
Average wind speed	u	3.6	m/sec	8.1	mph	NOAA, 1997a,b,c
Control efficiency		50	percent	50	percent	EPA, 1998b
Days with rain	p	91.4	days	91.4	days	NOAA, 1997a,b,c
Moisture content	M	8	percent	8	percent	EPA, 1998b
Project duration		5	years			Appendix D
Silt content	s	7	percent	7	percent	EPA, 1998b
Weight of fill material		1.48	MT/m^3	1.25	ton/cy	

The Natural River Drawdown Engineering Appendix (Appendix D) provides conceptual designs for removing the four lower Snake River dams, creating river channelization, and reservoir modifications. Within Appendix D, the Embankment Excavation Plan presents an estimate of the volume of fill material that would be removed from each site. The River Channelization Plan calls for construction of levees at each site following embankment removal. Between 200,000 and 300,000 cubic yards (cy) of material are required for the levees at each site. This emissions analysis includes an additional 191,139 cubic meters (m^3) (250,000 cy) for the levees. The volume of material excavated and the quantity of material needed for the levees is presented in Table 3-3.

Table 3-3. Excavation Quantities

	Excavation Volume (m^3)			
Material	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Core material	7,500	78,300	138,300	240,200
Gravel fill	59,500	675,200	978,000	1,101,700
Coffer dams			263,900	276,400
Levees	191,139	191,139	191,139	191,139
Total	258,139	944,639	1,571,339	1,809,439

Note: Updated excavation volumes are available in Appendix D, Table B1.

Source: Appendix D, Natural River Drawdown Engineering.

When excavated, the core material will be saturated with water and will not be a source of particulate matter emissions. However, this material is a small percentage of the total volume of material to be excavated and was included in the analysis. The material excavation rate ranges from about 920 to 1,920 m^3/hour (1,200 to 2,500 cy/hour). Two truck types, 35 and 85 tons, will haul the material to stockpiles about 3 km (2 miles) from the site (the exact location has not been specified). Haul road emissions are based on the volume of material excavated, the number of trips, and the length of each round trip. The emission calculations assume that good construction practices will be followed to minimize road dust. This analysis assumes that construction practices will reduce haul road fugitive dust emissions by 50 percent.

Emissions generated by the batch dropping of truckloads are estimated from the volume of material excavated. Bulldozer and grader emissions are based on the number of hours of operation estimated for this equipment (Table 3-4).

Table 3-4. Deconstruction Engineering Data

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Bulldozer hours	50,359	37,177	34,048	44,345
Total material volume (m^3)	258,139	944,639	1,571,339	1,809,439
Batch drop volume (m^3)	258,139	944,639	1,571,339	1,809,439
Grader hours	50,359	37,177	34,048	44,345

Source: Appendix D, Natural River Drawdown Engineering.

The Natural River Drawdown Engineering Appendix (Appendix D) includes a number of plans for reservoir modifications, including bridge modifications, reservoir embankment protection, treatment of drainage structures, railroad and roadway repair, and modification to recreation sites. Construction details sufficient for emission estimates have not been specified. Reservoir modifications may include, but are not limited to, placement of fill material, rip-rap, rock, and concrete, as well as excavations of fill material. Construction activities may include use of haul roads and heavy equipment such as bulldozers and graders. The location and schedule of these activities, types of material to be placed or removed, and the volume of material involved have not been specified. Therefore, emissions associated with reservoir modifications have not been included in this analysis.

Structural enhancements to improve the downstream migration of juvenile salmon would be added to each of the lower Snake River facilities under the Major System Improvements Pathway. Most of these enhancements are surface bypass and collection (SBC) systems. Details of the enhancements are presented in the Existing Systems and Major System Improvements Engineering Appendix (Appendix E).

The SBC structures would be built in place, or would be built offsite and assembled onsite. Assuming that onsite construction would be employed, the emission sources for the Major System Improvements Pathway include construction-related activities such as cement mixing and unpaved road emissions. Small emissions would result from loading cement, sand, aggregate, and water into mixer trucks. Particulate matter, primarily cement dust from the mixer trucks, is the pollutant of concern. EPA emission factors for truck-mixed concrete are 0.01 kg/MT of cement (0.04 lb/cy).

Construction-related emissions for the Major System Improvements Pathway would be very small. To provide emission quantities for a comparison of the alternatives, construction related emissions have been assumed to equal 1 MTY (1 TPY) for all four hydrofacilities. While unknown at this time, it is possible that modifications in farming patterns due to regional economic changes (such as shifts from irrigated to dryland farming) could also lead to changes in emissions.

3.2 Loss of Barge Traffic

In 1994, over 38.1 million kgs (4.2 million tons) of freight passed through the locks at Ice Harbor Dam (Lee and Casavant, 1996). Nearly all of this commerce was downriver transportation of farm products. Waterborne transportation is characterized as follows:

- Farm products comprise 81 percent of the downriver transport and 78 percent of the total commerce.
- Forest products comprise 16 percent of the downriver transport and 15 percent of the total commerce.
- Petroleum products comprise 70 percent of the upriver transport and 3 percent of the total commerce.
- Fertilizers and chemical products comprise 14 percent of the upriver transport and less than 1 percent of the total commerce.
- Manufactured products comprise 14 percent of the upriver transport and 3 percent of the total commerce.

The Natural River Drawdown Pathway would require a shift from barge transportation to train and truck transportation, which would change the quantity and distribution of vehicle emissions. Air emissions are estimated from the number of river, train, and road miles required to transport commodities affected by the Natural River Drawdown Pathway. Data for this analysis are available from two sources. The Eastern Washington Intermodal Transportation Study (EWITS) conducted a number of studies, including an examination of energy consumption and air emissions associated with a Snake River drawdown. The Transportation Analysis (DREW, 1999b) provides the number of train and truck bushel-miles needed to transport the wheat and barley harvest following drawdown. In addition, the change in the number of trucks hauling wheat and barley on selected Washington highways has been estimated.

3.2.1 Eastern Washington Intermodal Transportation Study

EWITS is a 6-year study jointly funded by the Federal government and the Washington State Department of Transportation. EWITS was established to facilitate existing regional and state-wide transportation efforts, forecast freight and passenger transportation service needs for eastern Washington, identify gaps in eastern Washington's current transportation infrastructure, and pinpoint transportation system improvement options critical to economic competitiveness and mobility. Data presented in several EWITS reports were incorporated into this emissions analysis.

EWITS examined the energy consumption and air emission impacts associated with a Snake River drawdown (Lee and Casavant, 1998). The study calculated the energy used and emissions created by transportation modes (barge, train, and truck) for the 1994 eastern Washington wheat and barley harvest. Two cases were investigated: a base case modeled transportation modes currently available, and the second scenario examined the effects of not having barges available on the Snake River. The modeling was accomplished by using a Geographic Information System (GIS) database and a General Algebraic Modeling System (GAMS) optimization system. The GIS/GAMS model determines minimum distances and least-cost routes and modes to transport wheat and barley from farms to Portland. The model organizes the data by ton-mile of wheat and barley, sorted by transportation mode. Energy consumption and emissions factors are expressed in units of ton-miles.

Comprehensive transportation modeling would account for a number of conditions, including vehicular performance, weight factors, infrastructure quality, pre- and post-trips, and climatic conditions. The GIS/GAMS modeling accounted for several of these factors. The Lee and Casavant study included two truck types, single unit three-axle trucks and combination tractor and trailer five-axle units, differentiated by their tare weight. Locomotive energy consumption and emissions data available from literature were used in the study (EPA 1997b). Branch line locomotives are assumed to have the same characteristics as main line locomotives.

Comprehensive marine vessel emissions were not readily available until Lloyds Register published the results of a testing program in 1995. Additional emission testing has been conducted in California, Vancouver, B.C., and on Coast Guard vessels. Marine emissions are a function of vessel deadweight, engine horsepower, speed (for example, idle, maneuvering, cruse), and load. Towboat emissions used in the EWITS modeling are compatible with the following:

- British Columbia Ferries Emissions Test Program, by G. Rideout for the Environment Canada in 1998.

- Commercial Marine Vessel Contributions to Emission Inventories, by Booz Allen & Hamilton for the Environmental Protection Agency in 1991.
- Emission Testing of Nonroad Compression Ignition Engines, by J. N. Carroll and C. M. Urban of the Southwest Research Institute for the Environmental Protection Agency in 1995.
- Port of Vancouver Marine Vessel Emissions Test Project, by G. Rideout and E. Radloff for the Environment Canada in 1997.
- Shipboard Marine Engine Emission Testing for the United States Coast Guard, by Environmental Transportation Consultants for the Volpe National Transportation System Center and the United States Coast Guard Headquarters Navel Engineering Division.

Energy consumed and emissions from pre- and post-trip moves are ignored in the modeling study. Speed and road gradients are also not taken into account in the modeling. The model assumed that the entire crop was transferred to the Portland, Oregon, area for export, and no grain was retained in storage. The model does not account for the possibility of rail car shortages. Finally, the study examined only the transportation of wheat and barley from the eastern Washington producing areas to the Portland seaport.

Air pollutant emission factors for diesel-fueled engines, available from EPA and others, are presented in units of pound of emitted pollutant per gallon of fuel (lb/gal). The uncontrolled emission factors were derived from EPA procedures for preparing mobile source emission inventories, and are presented in Table 3-5. Fuel usage for locomotives, trucks and towboats were reported as the amount of energy required to move 907.2 kgs (1 ton) of a commodity 1.6093 kms (2 mile) (Btu/ton-mile). A British thermal unit (Btu) is the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit (°F). One gallon of diesel fuel is equivalent to about 137,000 BTUs. Energy requirements by transportation mode are presented in Table 3-6. The Lee and Casavant study used uncontrolled emission rates.

Table 3-5. Mobile Source Emission Factors

	Emission Factors (lb/gal)				
Mode	**CO**	**HC**	**NO_x**	**PM_{10}**	**SO_2**
Towboat	0.057	0.019	0.419	0.009	0.075
Locomotive	0.059	0.022	0.564	0.015	0.036
Truck, 3-axle	0.023	0.212	0.093	0.014	0.005
Truck, 5-axle	0.023	0.212	0.093	0.016	0.006

Sources: EPA, 1985, 1992, and 1997b. Lee and Casavant, 1998.

Table 3-6. Energy Requirements by Transportation Mode

Mode	Energy Requirement (Btu/ton-mile)
Towboat	374
Locomotive	372
Truck	551

Source: Lee and Casavant, 1998.

Air pollutant emissions for each transportation mode are determined as follows:

$$E_{ap} = EF_{ap} * T * M * EC / 137{,}000 \text{ Btu/gal}$$

where:

E_{ap} is the emission for each air pollutant, in lb

EF_{ap} is the emission factor for each air pollutant, in lb/gal (from Table 3-5)

T is the total tonnage for the transportation mode

M is the number of miles, and

EC is the energy consumed in Btu/ton-mile (from Table 3-6).

The GIS/GAMS model determined the optimal roads required to transport the grain harvest to elevators, the number of vehicles required to transport the harvest, and the emissions resulting from the trucks. Grain transportation, from elevators to rail and river terminals and on to terminals in the Portland area, were also simulated. Emissions from each transportation mode were summed. Total towboat, locomotive, and truck emissions, with and without the lower Snake River as a navigable waterway, were determined.

Wheat and barley ton-miles were used to estimate transportation emissions. Wheat and barley currently accounts for about 80 percent of the Snake River commerce, all of which would be shifted to highways and railroads. By the time that the drawdown and deconstruction become effective (2010), the amount of commodities normally shipped on the waterway is projected to increase. Furthermore, containers used to transport grain are often returned to the grain-producing areas empty. Therefore, to account for empty backhauls, the emissions were doubled. To account for all shipped commodities and the projected increase in shipments by 2010, the emissions were increased by 13 percent.

3.2.2 Transportation Analysis

The Transportation Analysis (DREW, 1999b) is an assessment of the economic effects of drawdown on regional transportation, including alternative shipping modes and costs, and a determination of the least-cost combination of storage, handling, and transport modes which would emerge in response to curtailment of waterborne transport. The economic analysis followed these steps:

1. Identify the origins and destinations of commodity groups that utilize the lower Snake River.
2. Develop costs for barge, train, and truck modes from transportation analysis models.
3. Estimate transportation costs associated with the Existing System (Base Case) and Natural River Drawdown Pathways with the assistance of a computer model.

Off-river origins of grain transported on the lower Snake River include areas within northeastern Oregon, eastern Washington, northern Idaho, and a small number of counties in the grain-producing areas of Montana and North Dakota. An estimate of the change in the number of bushel-rail-miles and bushel-road-miles resulting from drawdown, for 2010, was provided in the Transportation Analysis. Note that barge transportation on the Columbia River will continue. These data, presented in Table 3-7, form the basis of the air emissions estimates. Idaho truck bushel-miles are predicted to decrease as grain is hauled to closer elevators next to railroads.

Table 3-7. Change in Transportation Ton-Miles resulting from Drawdown

	Increase in Bushel-Miles		
State	**Barge**	**Train**	**Truck**
Idaho	1,887,112,064	7,497,500,697	(1,425,943,955)
Montana	963,991,772	138,647,791	646,835,856
Washington	10,867,157,100	4,521,760,226	2,619,068,814
Oregon	156,202,448	-	30,198,573
North Dakota	391,721,516	-	265,297,487

Source: DREW, 1999.

The limitations of the economic analysis are reflected in the emissions data. The economic analysis does not attempt to determine the extent that exports from the region may decline as a consequence of higher transportation costs. Non-grain commodities are not included. As inland navigation capacity is reduced, competing surface transportation modes are assumed to possess the required capacity, or would add capacity necessary to accommodate additional traffic. Market practices such as backhauls are incorporated in truck movements to the extent possible.

The wheat and grain harvest normally shipped down the Snake River would be transferred to trains and trucks for the Natural River Drawdown Pathway. The Transportation Analysis estimated the economic impact of this transportation mode shift. However, the Transportation Analysis did not estimate bushel-miles for river barges. Snake River towboat emissions for the Existing System (Base Case) Pathway are estimated from tons of goods shipped through the locks, river miles, and EWITS emission factors. The commodity tons are based on Corps 1994 shipping records (Lee and Casavant, 1996).

The Transportation Analysis estimated bushel-miles for trains and trucks hauling the entire 49.9-million-kg (5.5-million-ton) 1996 grain harvest without the Snake River waterway. In 1994, about 29.0 million kgs (3.2 million tons) of grain were shipped down river. The 1994 towboat emissions for the Existing System (Base Case) Pathway were increased by 58 percent to account for returning empty containers and the larger 1996 harvest.

Some of the 1996 harvest would be put on barges in the Tri-Cities area. The Transportation Analysis estimates include river-bushels, which were included in the emission estimates. To estimate transportation-related emissions for the Natural River Drawdown Pathway, bushel-river-miles, bushel-rail-miles, and bushel-road-miles were converted to ton-miles and multiplied by the EWITS emission factors. The emissions were doubled to account for locomotives and trucks returning empty containers, and were increased by 13 percent to account for other commodities normally shipped on the river and the increase in commodities shipped by 2010.

Two sources of transportation data are available. Emissions estimated with EWITS and the Transportation Analysis data are averaged for the Existing System (Base Case) and Natural River Drawdown Pathways.

3.2.3 Estimated Truck Counts Resulting From Drawdown

Grain harvested in eastern Washington is currently trucked from farms to elevators and on to river ports or the Tri-Cities area. With drawdown, grain would be trucked to elevators located next to rail lines, or would be trucked directly to the Tri-Cities area. Lee and Casavant (1998) modeled wheat and barley quantities on eastern Washington highways with and without the Snake River waterway. These grain quantities are combined with Washington State Department of Transportation (WSDOT) traffic counts on selected highways to estimate the change in the number of trucks.

Vehicle and truck counts for 1997, at selected locations, are presented in Table 3-8 (WSDOT, 1998). Modeling estimated the number of grain bushels on these roads (Lee and Casavant, 1998). The modeled number of bushels were converted to the number of trucks by assuming 60 pounds per bushel and 26 tons per truck load (DREW, 1999b). The number of trucks hauling grain was combined with the average daily truck counts to estimate the change in the number of trucks at select locations following drawdown.

Table 3-8. Traffic Counts

Highway	Intersection	Average Number of Vehicles per Day	Average Number of Trucks per Day
SR 395	SR 26	5,500	1,925
	SR 260	5,000	2,000
SR 127	SR 26	1,000	260
SR 195	SR 26	6,900	1,173
SR 26	SR 395	2,400	336
	SR 261	1,000	200
	SR 127	1,800	504
	SR 195	2,600	650

Source: WSDOT, 1998.

3.3 Windblown Fugitive Dust

In the past, the Corps has received public comments regarding fugitive particulate matter associated with drawdowns of Lake Koocanusa. Residents of Eureka, Montana, about 13 km (8 miles) east of the reservoir, believe that the seasonally exposed reservoir sediments significantly contribute to blowing dust problems. In response to this concern, the Corps conducted a PM_{10} monitoring program in the Eureka/Lake Koocanusa area (Environalysis, 1996). The Results of this study indicated that although 1-hour PM_{10} concentrations were sometimes high, the annual and 24-hour concentrations remained below the AAQS, both at the edge of the lake and in the town of Eureka.

Without the advantage of onsite data, it is difficult to estimate PM_{10} concentrations expected from windborne fugitive dust. Particulate matter concentrations are a function of many variables, including:

- The area of exposed dry sediments
- The amount of fine particulate matter in the sediments

- The sediment moisture content
- The frequency that the surface is disrupted, providing fresh material for wind erosion
- The frequency and duration of winds strong enough to lift erodible particles
- The roughness of the exposed surface (a smooth surface versus one impregnated with rocks and other obstacles).

To gain some understanding of the nature of the blowing dust problem as it may apply to the lower Snake River reservoirs, the impact evaluation includes an example of a PM_{10} emission calculation. Wherever possible, information relevant to the lower Snake River reservoirs is included in the analysis, along with a description of the representativeness and limitations of the data.

Wind-generated erosion is dependent upon the amount of erodible material present, the roughness of the surface, the surface wind speed, and the frequency with which the surface is disturbed. Particulate matter emission rates would rapidly decrease as the erodible material is removed from the surface. If the surface remains undisturbed or wet, the amount of erodible material is limited. EPA has developed a method to predict the amount of particulate matter emitted during a wind erosion event (EPA, 1998b). The method used to estimate PM_{10} emissions and the frequency that they occur is summarized as follows:

1. Determine an appropriate threshold frictional velocity, a measure of the wind stress on the erodible surface, for the dry sediments.
2. Determine the maximum fastest mile. Emissions resulting from this wind speed represent an upper limit of fugitive emissions in the region.
3. Determine a relationship between the peak gusts and 1-hour average wind speeds. It is assumed that this relationship is true for the fastest mile, the variable appropriate for the maximum emissions.
4. Convert the threshold frictional velocity to a 10-meter measurement, and convert this value to an equivalent 1-hour average wind speed.
5. Scan the meteorological database and determine the number of wind speed observations greater than the threshold frictional velocity.
6. Compute hourly emission factors for frictional velocities that range from the threshold frictional velocity to the maximum fastest mile.
7. Estimate hourly PM_{10} emissions from the emission factors, hourly meteorological data, and the area of exposed sediments.
8. Sum the hourly emissions and compute an annual average PM_{10} emission rate for the 4 reservoirs.

Blowing dust conditions are most likely to occur during months with the greatest number of clear days, the greatest number of days with hot temperatures, and the smallest number of days with precipitation. Low relative humidity also contributes to the potential for blowing dust. The months with the greatest potential for fugitive dust are July through September (Technical Annex A).

The frictional velocity is a measure of the wind stress on the erodible surface. The threshold frictional velocity represents the wind shear necessary to begin to move the erodible surface particles. If the frictional velocity exceeds the threshold frictional velocity, wind erosion would occur. The frictional velocity is a function of the material being eroded. For silty clay soils typical of the material that may be found in sediments, the threshold frictional velocity is 0.64 m/sec (1.43 mph) (Gillette, 1988).

The meteorological variable that best reflects the magnitude of wind gusts that lift surface dust is the fastest mile (EPA, 1998b). This quantity represents the wind speed corresponding to a mile of wind movement past the anemometer in the least amount of time. Fastest mile measurements for the three meteorological monitoring stations used in this study (Pendleton, Spokane, and Yakima) are available for periods on the order of 40 years (Technical Annex A). The highest fastest mile value is 34.4 m/sec (77 mph).

The fastest mile, measured at a height of about 10 meters above the surface, is not representative of near-surface wind speeds. By assuming a logarithmic wind speed profile, the near-surface frictional velocity may be estimated (EPA, 1998b):

$$u_{fv} = 0.053 * u_{fm}$$

where u_{fv} = frictional velocity (m/sec)

u_{fm} = fastest mile at 10 m (m/sec)

The expression above is valid for a surface roughness of 0.5 cm. Surface roughness is proportional to the dimension of the objects penetrating the surface. A low surface roughness is assumed for smooth sediments. The expression above can be used to convert the threshold frictional velocity to a 10-meter wind speed and the fastest mile to a frictional velocity. The frictional velocities range from 0.64 to 1.82 m/sec (1.43 to 4.08 mph). The corresponding 10-meter fastest miles range from 12.1 to 34.4 m/sec (27.1 to 77.0 mph).

The meteorological database used in this analysis corresponds to the period when peak gusts began to be included in the climatic summaries. Assuming that the maximum 1-hour wind speed for a particular month includes the peak gust, a relationship between peak gusts and 1-hour average wind speeds was developed (Figure 3-1). Hourly average wind speeds are about 62 percent of the peak gusts. The hourly average wind speeds corresponding to the threshold and maximum frictional velocity can then be determined. This assumes that the expression above, used to convert fastest mile measurements to frictional velocities, is valid for peak gusts. The corresponding threshold and maximum 1-hour wind speeds measured at 10 meters are 7.47 and 21.2 m/sec, respectively (16.7 and 47.5 mph).

Mean atmospheric winds are not sufficient to sustain wind erosion. However, wind gusts may quickly deplete a substantial portion of the material available for erosion. Historical measurements of the peak gust are available in annual climatological summaries for Pendleton, Spokane, and Yakima (Technical Annex A). These data represent short period wind speeds. Sustained high-speed wind events are also an important mechanism for suspending large amounts of dry lake sediments. The meteorological database used to develop the Pendleton, Spokane, and Yakima wind rose figures (Section 2) was scanned to determine the frequency of occurrence of 1-hour average winds greater

than the threshold frictional velocity. For all three meteorological monitoring locations, the number of hours of high wind speeds quickly decreases with increasing speeds (Figure 3-2). Wind events strong enough to move surface material occur at a frequency of between 5 and 10 percent of the hours in a year. Hourly average wind speeds greater than 16 m/sec (36 mph) occur about once per year.

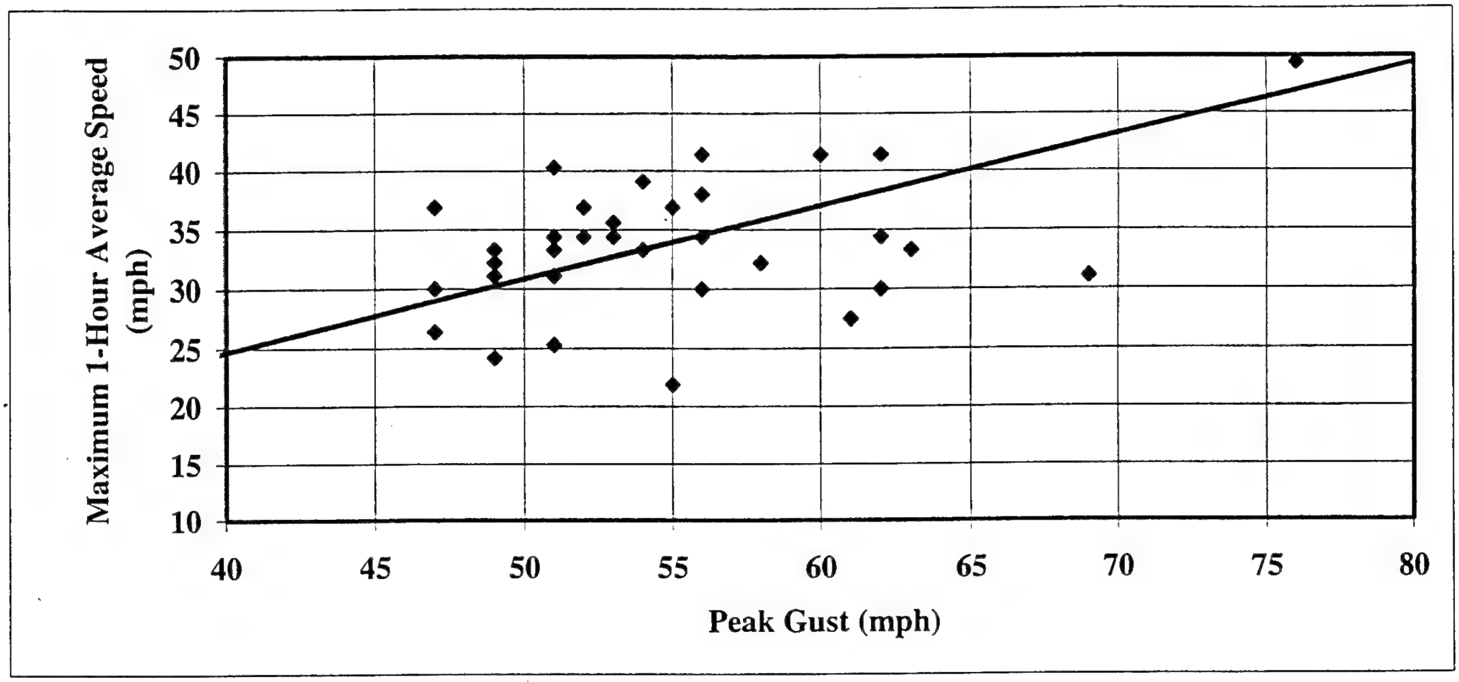

Figure 3-1. The Relationship Between Peak Gusts and One-Hour Average Wind Speeds

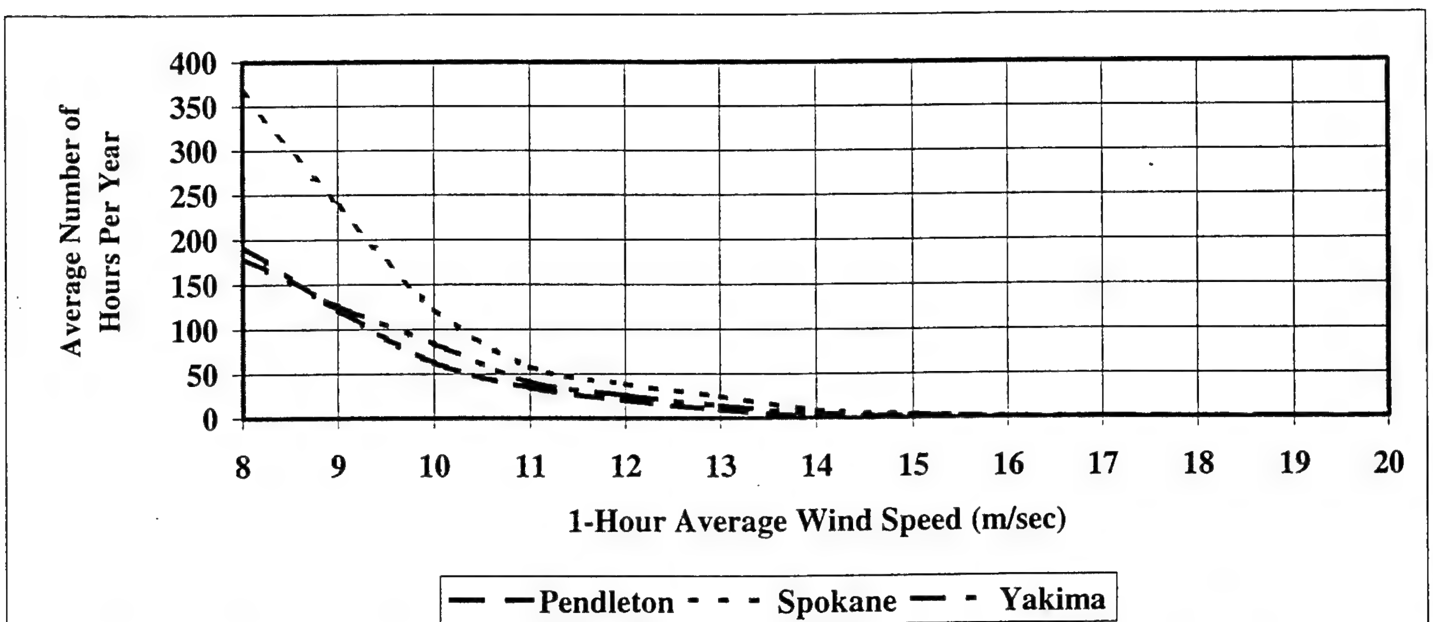

Figure 3-2. Average Number of Hours Per Year of High Wind Speed Events

The amount of material removed from the surface is a function of the difference between the wind velocity at the surface and the velocity required to erode the surface, and may be expressed as follows (EPA, 1998b):

$$EF_F = k * (58(u_{fv} - u_{tv})^2 + 25(u_{fv} - u_{tv}))$$

where EF_F = emission factor, in grams per square meter (g/m^2)

k = dimensionless aerodynamic particle size multiplier

u_{fv} = frictional velocity, in m/sec

u_{tv} = threshold frictional velocity, in m/sec

The expression above is valid for dry exposed material with limited erosion potential. The frictional velocity above is derived from the fastest mile. The emission expression assumes that the largest wind speed event between surface disturbances removes all available erodible material. If the surface is disturbed again, additional material becomes available for erosion by the next high wind event.

The amount of sediment with particle diameters less than 10 microns would be similar to the suspended load in the lower Snake River. Particle size distribution measurements indicate that about 20 percent of the particles are less than 10 microns. For this study, the value of k in the emission factor expression above is equal to 0.2.

The expression above was used to compute PM_{10} emission factors, in units of g/m^2, as a function of average 1-hour wind speeds greater than the threshold frictional velocity. The emission factors are presented in Figure 3-3. Emission factors used in this study are comparable to the calibrated CP^3 dust emissions (Claiborn et al., 1998) Actual emissions would also depend on the amount of dry sediments available. After the lighter surface material has been removed, additional material would not be available until the surface is disturbed. This analysis assumes that the amount of erodible material is not limited.

Annual windblown emissions are calculated from wind speed-dependent emission factors, the number of hours of wind speeds greater than the threshold frictional velocity, and the area of exposed dry sediments. The surface area of each of the four lower Snake River reservoirs is presented in Table 3-9. According to the Natural River Drawdown Engineering Appendix (Appendix D), revegetation would be accomplished in the following phases:

- Initial seeding at 2-week intervals would take place during the drawdown period.
- Drill seeding would be performed during the following spring to revegetate areas where the initial seeding did not take.
- Trees would be planted during the second spring following drawdown.
- Annual efforts would be made to reestablish vegetation in problem or disturbed areas.

The entire area of each reservoir would not be exposed to wind erosion at one time. Therefore, the amount of dry lake sediments exposed to erosion would be less than the values presented in Table 3-9. Furthermore, the Corps would restrict access to the lake sediments, further limiting surface

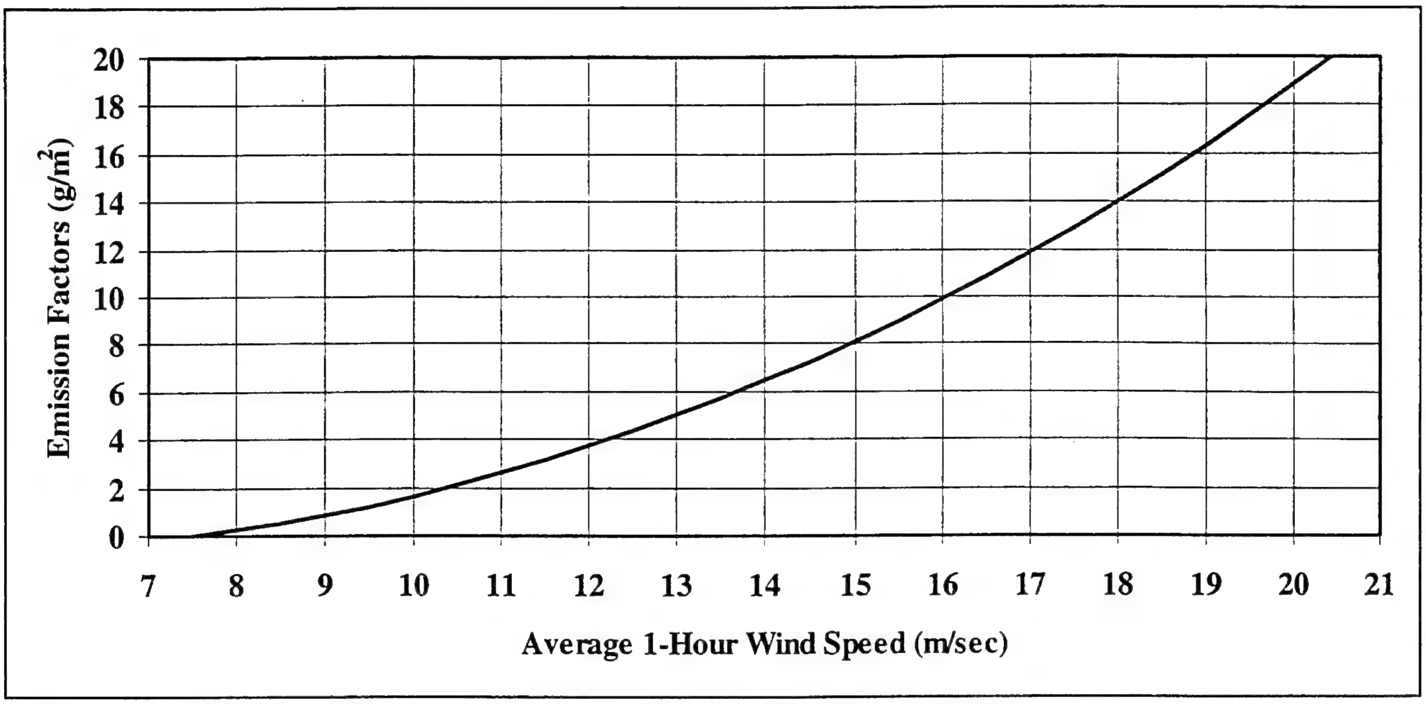

Figure 3-3. PM_{10} Emission Factors by 1-Hour Average Wind Speed

Table 3-9. Area of Lower Snake River Reservoirs

Facility	Area (Acres)	Area (m^2)	Area (km^2)
Ice Harbor	8,375	33,892,558	33.9
Lower Monumental	6,590	26,668,890	26.7
Little Goose	10,025	40,569,898	40.6
Lower Granite	8,900	36,017,166	36.0
Total	33,890	137,148,526	137.1

disturbances and the availability of erodible material. Test areas at Owens Lake indicate that a 99 percent reduction in emissions is possible with only 50 percent of the dry sediment covered by vegetation. This analysis conservatively assumes that these measures to reduce wind erosion would reduce emissions by 90 percent.

3.4 Replacement Power Generation

Hydropower generation does not result in air pollutant emissions. The loss of the Snake River hydropower facilities would require replacement of power-generating capacity, which could result in an increase of criteria air pollutants, TAPs, and GHGs. The Technical Report on Hydropower Cost and Benefits (DREW, 1999a) investigates the economic consequences of the loss of hydropower and evaluates the power production alternatives.

Electricity is bought and sold throughout the western United States, and parts of Canada and Mexico. Changes in power production in the Pacific Northwest could result in changes to power production, and hence atmospheric emissions, in all regions of the Western System Coordinating Council (WSCC). WSCC electric generating resources include a mix of thermal power plants that burn coal, natural gas, and oil (DREW, 1999a). This air quality analysis attempts to estimate how emissions would change on a regional basis because of the loss of the lower Snake River hydropower, and is based on the findings of the Technical Report on Hydropower Cost and Benefits.

The Technical Report on Hydropower Cost and Benefits (DREW, 1999a) investigates how the current power system functions and how the system would change with the Natural River Drawdown Pathway. Models are used to assist with the analysis. Hydro regulation models determine how much hydropower generation would occur for different water years and various Feasibility Study alternatives. Power system models estimate the generating resources required to meet demand. The power system models incorporate changes resulting from deregulation of the electrical industry and changes in the wholesale power market. The power system models also include economic factors such as fuel costs and the marginal cost of production. The power system model PROSYM incorporates fuel costs, variable operating and maintenance costs, and startup costs for each generating unit, and it has an air pollution emission subroutine. Fuel type, heat rate, down time, output, and the retirement date of the generating units are included in the model. The generating units are dispatched by PROSYM in order of increasing costs, unless fuel supply contracts or other factors require a specific dispatch.

PROSYM predicts which of the approximately 2,000 WSCC generating units would be used to meet power demands on an hour-by-hour basis. The determination of which generating units are on-line is performed primarily by economic factors – the least costly units are turned on first, while the older, less efficient, plants with greater emissions are turned on last. The number of operating hours per year are determined for each of the approximately 2,000 WSCC generating units. Air emissions are estimated from actual emission rates for each of the thermal generating units multiplied by the predicted number of operating hours for that unit. The emission factors are obtained from actual emissions reported to EPA in annual emission reports. The model is limited to CO_2, NO_x, and SO_2 emission factors and will be provided upon request. Details regarding the PROSYM model are presented in the DREW report (1999a).

Over time, new power plants would be built throughout the WSCC to meet growth demand, for all pathways. The PROSYM model uses a market price approach to determine costs associated with replacement power generation. It is assumed that the new plants would be natural gas-fired, combined-cycle combustion turbines, currently the most economically feasible power plants being built. The new plants are assumed to have emission factors equal to the latest combined cycle plants built in each WSCC region.

PROSYM evaluated generating capacity requirements for several cases:

- A1 – The Snake River hydrofacilities are in place. This case represents the existing system conditions projected to 2010.
- A2 – The Snake River hydrofacilities are in place and include fish passage enhancements. This case represents Major System Improvements, projected to 2010.

- A3 – The Snake River hydrofacilities are breached. This case represents the Natural River Drawdown Pathway projected to 2010.

Slightly more hydropower would be generated with case A2. The change in emissions from case A1 to A2 is very small and was not quantified by the Power System Analysis. Case A3 consists of 1,550 megawatts (MW) of replacement capacity, including extra capacity to support transmission reliability. All new power plants would be built somewhere in the Pacific Northwest. The demand for energy will continue, resulting in a need for additional generating capacity. All cases include additional natural-gas-fired, combined-cycle, combustion turbine power plants, which will go online by 2010, with or without Snake River hydropower.

The siting of new power plants may be a critical factor. The modeling did not consider air-shed limitations. It is assumed that new power plants added to the regions would meet all applicable Federal, state, and local air quality regulations. It must be emphasized that the results of the analysis are hypothetical. The real world response to increasing power demand, with and without the loss of lower Snake River hydropower, may be different than predicted in the WSCC regions. The PROSYM emission estimates are representative of 2010, based on projected population growth and energy requirements.

The PROSYM model estimates CO_2, NO_x, and SO_2 emission from thermal power plants in the western United States. These estimates are extrapolated to CO, VOCs, PM_{10}, and other pollutants by use of published emission factors. Coal, fuel oil, and natural gas emission factors are available from EPA (1998b). The emission factors depend on firing practices (dry bottom firing, tangentially fired, and spreader stoker) and control technologies (cyclones, multiple cyclones, scrubbers, precipitators, and baghouses). Average uncontrolled emission factors for coal, diesel, natural gas, and oil combustion are presented in Table 3-10. These criteria and HAP emission factors assume an average sulfur content for coal, natural gas, and oil equal to 3, 0.3, 1.0, and 1.0 percent, respectively.

Table 3-10. Average Uncontrolled Combustion Emission Factors

Pollutant	Coal Combustion (lb/ton)	Natural Gas (lb/hp-hour)	Fuel Oil (lb/hp-hour)
CO	5.5	0.000860	0.000384
CO_2	5652.5	0.876	1.32
NO_x	16.4	0.00353	0.00560
PM_{10}	11.9	0.000335	0.000489
SO_2	110.7	0.000226	0.00809
TOC	0.24	0.000192	0.000137
Benzene	0.0013	-	-
Formaldehyde	0.00024	0.0000216	0.0000104

Source: EPA, 1998b.

To determine emissions of other pollutants, the estimated CO_2, NO_x, and SO_2 emissions were multiplied by the ratio of the emission factors. For example, to estimate CO emissions for natural gas combustion, the natural gas CO_2 emissions were multiplied by the natural gas CO emission factor and divided by the natural gas CO_2 emission factor. NO_x emissions were used to derive VOC,

benzene, and formaldehyde emissions (all of these pollutants are ozone precursors). PM_{10} emissions were derived from SO_2 emissions (lean fuels such as natural gas emit very few of these pollutants). This approach assumes that emission controls applied to CO_2, NO_x, and SO_2 emissions apply to other pollutants. CO emissions will be overestimated because CO_2 is not normally controlled.

The independent power producers (IPP) frequently have a mix of generating types. Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) are mostly natural gas-fired units, with a few coal combustion units. These resources have been treated as all natural gas units by this analysis. San Diego Gas and Electric (SDG&E) operates only natural gas-fired plants.

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4. The Pathways and Their Impacts

This chapter compares air quality impacts associated with the Existing System (Base Case), Major System Improvements, and the Natural River Drawdown Pathways. The Existing System (Base Case) includes an estimate of emissions associated with current conditions.

4.1 Existing System (Base Case)

For the Existing System (Base Case), the lower Snake River facilities would remain in place and barge traffic would continue on the Snake River waterway. No changes are planned for this alternative. Emissions estimates presented in this alternative represent existing conditions, or emissions representative of a baseline year.

4.1.1 Demolition-Related Fugitive Emissions

Construction and demolition activities would not take place under the Existing System (Base Case). Therefore, no demolition-related atmospheric emissions would result from this pathway.

4.1.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Columbia and Snake rivers would continue with the Existing System (Base Case). Although there would not be any new air quality impacts, emission estimates for this alternative are used to predict the changes associated with the Natural River Drawdown Pathway. Emissions have been estimated from two data sources. The EWITS and Transportation Analysis studies use different methods to estimate transportation-related impacts for the Natural River Drawdown Pathway. Methods used to estimate air emissions were presented in Section 3.

4.1.2.1 Eastern Washington Intermodal Transportation Study

The Corps tracks freight shipments by commodity through the lower Snake River locks. These data were assembled as part of an EWITS investigation of waterborne commerce. Upriver and downriver commodity tons for each of the lower Snake River dams are presented in Table 4-1 (Lee and Casavant, 1996). Table 4-1 is based on 1994 data, the same year wheat and barley transportation were modeled (Lee and Casavant, 1998). The 1994 harvest consisted of about 132 million bushels of wheat and 17 million bushels of barley.

There are 20 grain-producing counties in eastern Washington. Grain movements begin at the farm and pass through 695 township centers and 400 grain elevators. The next destination is elevators at river ports or rail lines. Intermediate destinations include short- and long-term storage stations and consolidation points. About 60 percent of the harvest is shipped from production areas to elevators, the remaining 40 percent is trucked directly to river ports (Jessup, Ellis, and Casavant, 1997). Production areas located away from the Snake River ship grain by truck to intermediate storage or elevators adjacent to railroads. Barley is divided between township to river port elevators (62 percent) and township to feedlot (38 percent) shipments.

Grain loaded onto barges travels by river to Portland, Oregon. Grain trucked to intermediate storage locations is subsequently trucked to elevators with rail loading facilities. Grain loaded onto railroad cars is unloaded at export elevators in the Portland area.

Table 4-1. Lower Snake River Commodity Tonnage for 1994

	Up River				Down River			
Commodity	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Gasoline, jet fuel, and kerosene	48,494	48,494	48,494	48,494	226	226	226	226
Distillate, residual, and other fuels	80,577	80,577	80,577	80,577	35	35	35	35
Petroleum pitches, asphalt, naphtha	1,230	1,230	1,230	1,230	0	0	0	0
Fertilizer	23,139	24,232	24,232	7,232	500	500	500	0
Organic industrial chemicals	2,840	2,840	2,850	2,850	242	242	242	242
Forest products	1,596	1,596	1,596	0	636,627	711,051	710,376	704,204
Pulp and waste products	0	0	0	0	11,426	11,426	11,426	11,426
Sulfur, clay and salt	0	0	0	0	7,436	7,436	7,436	7,555
Paper and allied products	0	0	0	0	99,289	99,077	99,083	98,200
Primary non-ferrous metal products	20,743	21,732	22,621	23,203	1,818	1,624	1,559	1,674
Primary wood products	0	0	0	0	15	15	15	15
Wheat	4,200	4,100	14,700	600	3,060,772	2,460,057	2,318,521	1,209,057
Rye, barley, rice, sorghum, oats	0	0	0	0	136,392	138,664	130,664	51,022
Oilseed (soybean, flaxseed, others)	0	0	0	0	3,750	3,750	3,750	3,833
Vegetable products	0	0	0	0	56,788	57,081	57,091	57,989
Animal feed, grain mill products, flour	0	0	0	0	1,593	1,593	1,593	1,593
Other agricultural products	0	0	0	0	69	69	69	69
Barged fish	0	0	0	0	698	618	478	0
Manufactured equipment, machinery	1,800	1,800	1,800	30	805	156	156	136
Commodity unknown	2,955	1,230	1,230	0	1,322	456	456	341
Total	187,574	187,831	199,330	164,216	4,019,803	3,494,076	3,343,676	2,147,617

Source: Lee and Casavant, 1996

In the energy consumption and emissions study, commodity movements were expressed as ton-miles by transportation mode (Lee and Casavant, 1998). Ton-miles for the 1994 wheat and barley harvest by transportation mode are presented in Table 4-2. Transportation-related air emissions for wheat and barley shipments are presented in Table 4-3.

Table 4-2. Ton-miles for the 1994 Wheat and Barley Harvest with Snake River Barge Transportation

Mode	Wheat (million ton-miles)	Barley (million ton-miles)
Barge	827.4	76.3
Train	281.9	0.037
Truck	383.5	52.1
Total	1,492.8	128.4

Source: Lee and Casavant, 1998.

Table 4-3. Unadjusted Wheat and Barley Transportation Related Emissions for Snake River Towboats

		Emissions (tons)				
Mode	Commodity	CO	VOC	NO_x	PM_{10}	SO_2
Barge	Wheat	64	21	473	10	85
	Barley	6	2	44	1	8
Train	Wheat	23	8	216	6	14
	Barley	0.003	0.001	0.028	0.001	0.002
Truck	Wheat	18	164	72	12	5
	Barley	2	22	10	2	1
Total		113	218	814	31	112

Source: Lee and Casavant, 1998.

About 80 percent of the wheat harvest is transported to Portland by barge. Towboats on the Columbia and Snake Rivers account for the greatest amount of emissions. About 20 percent of the harvest arrives in Portland by rail. Trucks are used to move the harvest from producers to storage locations and on to river or rail terminals. The emissions presented in Table 4-3 are underestimated. The EWITS modeling did not include barge, train, and truck return trips and considered only wheat and barley. Most of the Portland-bound barges and rail cars return empty to eastern Washington.

According to Lee and Casavant (1996), wheat and barley account for about 78 percent of the total downriver commerce passing through the Bonneville locks. Downriver transportation far exceeds the upriver movement. It is assumed that upriver shipments include empty barges (and, by inference, rail cars and trucks). Because wheat shipments dominate the eastern Washington to Portland commerce, it is assumed that total transportation-related emissions, estimated by EWITS, can be increased by an additional:

- 100 percent to account for barge, rail, and truck return trips and the Portland to eastern Washington shipments

- 13 percent to account for the other commodities and to project the shipments to levels representative of 2010.

Based on the EWITS data, transportation-related air emissions, in and adjusted for the above factors, are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	260	500	1,872	71	256

Trucks are used to haul grain from producers and intermediate storage locations to elevators adjacent to railroads and waterways. The flow over eastern Washington highways was simulated as part of EWITS GIS/GAMS modeling effort (Jessup, Ellis, and Casavant, 1997). Maps showing wheat and barley highway flows for the Existing Conditions Pathway are reproduced in Annex B.

4.1.2.2 Transportation Analysis

The Transportation Analysis (DREW, 1999b) analyzed the consequences of a transportation mode shift resulting from the Natural River Drawdown Pathway, and not conditions that represent the Existing System (Base Case). Towboat emissions for the Existing System (Base Case) are estimated from tons of goods shipped through the locks in 1994, river miles, and the EWITS emission factors. The emission estimates are presented in Table 4-4.

Table 4-4. Unadjusted Towboat Emissions for all Commodities, for Existing System (Base Case)

		River	Emissions (tons)				
	Tons[1/]	Miles	CO	VOC	NO_x	PM_{10}	SO_2
Down River							
Portland	4,019,803	206.0	64.4	21.5	473.6	10.2	84.8
Ice Harbor	4,019,803	25.7	8.0	2.7	59.1	1.3	10.6
Lower Monumental	3,494,076	30.3	8.2	2.7	60.5	1.3	10.8
Little Goose	3,343,676	33.0	8.6	2.9	63.1	1.4	11.3
Lower Granite	2,147,617	49.0	8.2	2.7	60.2	1.3	10.8
Up River							
Portland	187,574	206.0	3.0	1.0	22.1	0.5	4.0
Ice Harbor	187,574	25.7	0.4	0.1	2.8	0.1	0.5
Lower Monumental	187,831	30.3	0.4	0.1	3.3	0.1	0.6
Little Goose	199,330	33.0	0.5	0.2	3.8	0.1	0.7
Lower Granite	164,216	49.0	0.6	0.2	4.6	0.1	0.8
Total	TPY		102.4	34.1	753.0	16.2	134.8
	MTY		92.9	31.0	683.1	14.7	122.3

1/ Source: Lee and Casavant, 1996.

The Transportation Analysis estimated bushel-miles for trains and trucks hauling the entire 49.9–million-kg (5.5-million-ton) 1996 grain harvest without the Snake River waterway. In 1994, about 29.0 million kgs (3.2 million tons) of grain were shipped down river. The 1994, towboat emissions for the Existing System (Base Case) were increased by 58 percent to account for returning empty containers and the larger 1996 harvest. Base Case towboat emissions adjusted for return trips and the larger 1996 harvest are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	177	59	1,299	28	233

The emissions estimated from the EWITS and Transportation Studies employ different input data, modeling approaches, and objectives and produce different values. Because both studies include uncertainty, the emission estimates were averaged. Transportation-related emissions for the Existing System (Base Case) are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
MTY	198	254	1,438	45	222
TPY	218	280	1,586	49	245

4.1.3 Fugitive Dust

For the Existing System (Base Case), the four lower Snake River reservoirs would not be drained. Therefore, there would be no fugitive emissions from exposed reservoir sediments.

The air quality environment of eastern Washington is dominated by naturally occurring fugitive dust resulting from wind storms that take place primarily from September through November. The CP^3 program estimated total PM_{10} emissions during four storms from 1990 through 1993. The sources of fugitive dust were from rangeland, dry agricultural land including fallow lands and land with residue, and irrigated agricultural land. The emission estimates, using two different emission factor algorithms, in tons, are as follows:

	Total Emissions by Emission Factor Algorithms		Emitting Area
Storm Date	CP^3	Gillette	(acres)
November 23, 1990	11,905	24,992	5,288,528
October 21, 1991	19,070	186,621	2,391,476
September 11, 1993	234,792	127,868	2,033,916
November 3, 1993	20,834	89,177	2,881,732

These storms represent extreme events. According to the database used to generate the wind rose figures presented in Section 2, eastern Washington may experience an average of about 10 wind storm events of varying intensity each year from September through November.

The CP^3 program also predicted PM_{10} concentrations resulting from emissions during the two 1993 storms. The emissions and concentration modeling effort calibrated the predicted concentrations

with measured concentrations in eastern Washington. Plots of the predicted concentrations, reproduced from Claiborn et al., 1998, are presented in Annex C.

4.1.4 Emissions

Power generation by the four lower Snake River reservoirs would continue for this alternative, eliminating the need for replacement power. However, the demand for energy will continue, resulting in a need for additional generating capacity. The Technical Report on Hydropower Costs and Benefits (DREW, 1999a) evaluated the need for additional generating capacity and included additional natural gas-fired combined-cycle plants in their projections. Emission estimates for coal-, fuel oil-, and natural gas-fired generating units, produced by the PROSYM model for the A1 case (Existing System) are presented in Table 4-5. The CO_2, NO_x, and SO_2 emissions predicted by PROSYM were used to estimate emissions for other criteria and hazardous air pollutants presented in Table 4-5.

Emissions from generating units throughout the WSCC, representative of the Existing System (Base Case), for 2010, for all fuel types, in thousands of tons, are as follows:

Pollutant	CO	CO_2	NO_x	PM_{10}	SO_2	VOC	Benzene	Formaldehyde
1000 TPY	404	414,234	58	49	457	1	0.004	0.04

In the 7-year period from 1990 to 1997, the U.S. CO_2 emissions increased from 4,929 to 5,457 million metric tons (5,433 to 6,014 million tons). This represents an increase of about 11 percent (EPA, 1999). If GHG emission rates continue to increase at the same rate, national CO_2 emissions in 2011 would be about 6,683 million metric tons (7,367 million tons). The 2010 power plant CO_2 emissions presented above may be compared to the projected national emissions. Western U.S. electric utility CO_2 emissions represents 5.6 percent of the national CO_2 emissions.

4.2 Major System Improvements Pathway

Structural enhancements to improve downstream migration of juvenile salmon would be added to each of the four lower Snake River projects under this alternative. The proposed enhancements consist of various SBS systems. Details on the system enhancement alternatives and designs are provided in the Existing Systems and Major System Improvements Engineering Appendix (Appendix E).

4.2.1 Construction-Related Fugitive Emissions

System enhancements would consist of SBC systems combined with structural modifications at each facility. The SBC structures, consisting mostly of channels, may be built from components constructed offsite, or may be built in-place. Therefore, construction-related air emissions for this alternative would be very small and would include particulate matter emissions from mixer trucks and haul roads.

For comparison of alternatives, this analysis has conservatively assumed a total of 1 MT (1 ton) of PM_{10} emissions for all four structural enhancement projects. Furthermore, construction is assumed to take place in one year.

Table 4-5. Power Generating Emissions for A1 Case (Existing System)

	Emissions (thousands of tons)							
Generation Resource	**CO**	**CO_2**[1/]	**NO_x**[1/]	**PM_{10}**	**SO_2**[1/]	**VOC**	**Benzene**	**Formaldehyde**
Coal								
Arizona/New Mexico	76	77,952	16	19	173	0.2	0.0013	0.0002
Canada	45	45,916	8	8	75	0.1	0.0007	0.0001
Northwest	12	12,147	2	4	40	0.03	0.0002	0.00003
Rocky Mountains	117	119,825	24	18	165	0.3	0.0019	0.0003
Fuel Oil								
FO #2	0.3	1,142	0.04	0.004	0.4	0.001	-	0.0001
FO #6	0.01	37	0.003	0.0003	0.1	0.0001	-	0.00001
Natural Gas								
Alberta	0.2	213	0.003	0.0003	0.02	0.0002	-	0.00002
Arizona/New Mexico	5	5,000	1	0.07	0.03	0.04	-	0.004
British Columbia	0.4	358	0.004	0.0004	0.003	0.0002	-	0.00002
Future Combined Cycle	87	88,258	2	0.2	1	0.1	-	0.01
Northern California	11	10,947	1	0.08	0.1	0.05	-	0.005
PG&E IPPs	13	12,961	1	0.1	1	0.06	-	0.006
Pacific Northwest	9	8,856	0.2	0.02	0.1	0.009	-	0.001
Rocky Mountains	3	3,200	0.5	0.04	0.02	0.02	-	0.003
Rocky Mountains/Colorado	2	1,924	0.1	0.01	0.01	0.006	-	0.001
Southern California	13	12,987	1	0.06	0.1	0.03	-	0.004
SCE IPPs	12	11,758	1	0.1	3	0.06	-	0.007
SDG&E IPPs	1	753	0.1	0.01	0.01	0.004	-	0.0004
Total System Emissions	404	414,234	58	49	457	1	0.004	0.04

1/ Source: DREW, 1999a.

4.2.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Columbia and Snake rivers would continue with this alternative. Transportation air emissions would be identical to the emission estimates presented in the Existing System (Base Case) (Section 4.1.2).

4.2.3 Fugitive Dust

For this alternative, the four lower Snake River reservoirs would remain in their present condition. There would be no fugitive emissions from exposed reservoir sediments. Fugitive dust emissions from agricultural lands, as part the existing environment, were described in Section 4.1.3. The same emission conditions are applicable to the Major System Improvements Pathway.

4.2.4 Emissions

Power generation by the four lower Snake River reservoirs would continue, eliminating the need for replacement power and associated air emissions. However, the demand for energy will continue resulting in the need for additional generating capacity. The Power System Analysis evaluated the need for additional generating capacity and included additional natural gas-fired combined-cycle power plants in their projections (DREW, 1999a). Construction of these power plants will continue for the Existing System, Major System Improvements, and Natural River Drawdown Pathways. Emissions for case A2 (Major System Improvements) are very similar to the A1 (Existing System) case. Differences between the A1 and A2 cases were not quantified.

4.3 Natural River Drawdown Pathway

Air quality issues associated with the Natural River Drawdown Pathway include impacts from demolition-related emissions, loss of barge transportation, windblown fugitive dust from exposed dry sediments, and emissions from thermal power plants replacing hydropower.

4.3.1 Demolition-Related Fugitive Emissions

Deconstruction of the four lower Snake River dams will require a number of plans, described in the Natural River Drawdown Engineering Appendix (Appendix D). The steps required to deconstruct each dam include lowering the reservoir, excavating embankments, removing cofferdams, routing the river around concrete structures, constructing levees as necessary, riprap production, and hauling and stockpiling for bank protection of existing railroad embankment. Removing the core material of the dams and constructing levees would produce fugitive dust emissions. PM_{10} emission sources are material handling activities such as hauling, dumping, bulldozing, and grading.

The objective of this analysis is to provide general emission estimates for the purpose of comparing the alternatives. Many of the deconstruction details, such as the number, weight, and capacity of haul trucks, length of haul roads, rate of excavation, and location of stockpiles, can only be approximated at this time. Therefore, only a preliminary analysis of fugitive emissions is possible at this time. Estimates of the equipment hours required for the project are available and are used to estimate bulldozer and grader emissions. PM_{10} emissions from batch dropping and hauling activities are estimated from the volume of material excavated from each facility. The methodology for the emission calculations was presented in Section 3. Excavation quantities and equipment operating hours, obtained from the Natural River Drawdown Engineering Appendix (Appendix D), are presented in Tables 3-3 and 3-4, respectively. These data were used in the emission calculations.

Fugitive PM_{10} emissions were calculated from emission factor expressions, default data values, operating hours, and excavation volumes presented in Section 3. It is assumed that mitigation measures (for example, watering) will achieve a 50 percent reduction in haul road emissions. The estimated PM_{10} emissions are presented by dam and construction activity in Table 4-6. Little Goose and Lower Granite require cofferdams, which result in larger PM_{10} emissions. Assuming that all four dams are deconstructed in 2 years, the following PM_{10} emissions are estimated:

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
TPY	58	65	82	99

Table 4-6. Estimated Deconstruction PM_{10} Emissions

Operation	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Tons per year				
Bulldozer	3.54	2.61	2.60	3.12
Hauling	7.73	28.3	47.6	54.9
Dumping	0.5	0.2	0.3	0.3
Grading	46.5	34.3	31.5	41.0
Total	57.8	65.4	82.0	99.3

4.3.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Columbia and Snake rivers would cease with the Natural River Drawdown Pathway. Emission estimates for this alternative are compared to estimates for the Existing System (Base Case). Emissions have been estimated from two data sources. The EWITS and Transportation Analysis studies use different methods to estimate transportation-related impacts for the Natural River Drawdown Pathway. Methods used to estimate air emissions were presented in Section 3.

4.3.2.1 Eastern Washington Intermodal Transportation Study

Transportation of wheat and barley from eastern Washington to Portland was investigated by EWITS (Lee and Casavant, 1998). Two cases were modeled: the 1994 grain harvest with and without the availability of Snake River barge transportation. Transportation-related emissions for the Existing System (Base Case), for wheat and barley and extrapolated to other commodities, were presented in Section 4.1.2. Emission estimates presented below are for the non-Snake River case.

Grain normally shipped to Snake River ports would be trucked to elevators with rail loading facilities. Production areas away from the Snake River would truck grain to elevators adjacent to railroads. A sizable amount of grain would still be trucked directly from production areas to river ports at or below the Tri-Cities area. Elevator to river port shipments would decrease 21 percent, while elevator to Portland rail shipments would increase by the same amount. About 28 million bushels of wheat would switch from barges to trains. About 62 percent of the barley harvest is trucked to non-Snake River ports, and then barged to Portland. The volume of barley barged to Portland decreases only slightly without the Snake River.

Without the Snake River, truck traffic would be concentrated on roads that lead to and from the Tri-Cities, especially state route 395. The local and rural roads east of Pasco would also receive much of the increased truck traffic.

The modeled wheat and barley ton-miles are presented in Table 4-7 for the Natural River Drawdown Pathway. Comparison with Table 4-2 indicates that train and truck ton-miles will increase from 40 to 87 percent. Air emissions for wheat and barley transportation modes, unadjusted for return trips and other commodities, are presented in Table 4-8.

Table 4-7. Ton-miles for the 1994 Wheat and Barley Harvest without the Snake River

Mode	Wheat (million ton-miles)	Barley (million ton-miles)
Barge	503.2	55.8
Train	545.5	0.093
Truck	442.8	108.1
Total	1,491.5	164.0

Source: Lee and Casavant, 1998.

Table 4-8. Unadjusted Wheat and Barley Transportation Related Emissions without the Snake River

		Emissions (tons)				
Mode	Commodity	CO	VOC	NO_x	PM_{10}	SO_2
Barge	Wheat	38.3	12.8	281.6	6.0	50.4
	Barley	4.3	1.4	31.2	0.67	5.6
Train	Wheat	45.7	15.2	357.3	8.7	26.1
	Barley	0.016	0.005	0.122	0.003	0.009
Truck	Wheat	81.0	20.0	184.8	13.7	5.1
	Barley	19.8	4.9	45.1	3.4	1.3
Total		189.1	54.3	900.1	32.5	88.5

Source: Lee and Casavant, 1998.

The emission estimates presented in Table 4-8 are for wheat and barley. Emission estimates that account for other commodities and return trips are derived in the same manner as presented in Section 4.1.2. Total transportation-related emissions are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	259	611	1,932	82	208

The change in transportation-related emissions is the difference between the emissions for the Natural River and Existing System (Base Case), and is estimated as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	(1)	100	55	10	(44)

Trucks are used to haul grain from producers and intermediate storage locations to elevators adjacent to railroads and waterways. The flow over eastern Washington highways was simulated as part of EWITS GIS/GAMS modeling effort (Jessup, Ellis, and Casavant, 1997). Maps showing wheat and barley highway flows for the Natural River Pathway are reproduced in Appendix B.

4.3.2.2 The Transportation Analysis

Train and truck bushel-miles are estimated as part of the Transportation Analysis. These estimates represent the bushel-miles required to bring the wheat and grain harvest to market. With the Natural River Drawdown Pathway, grain quantities normally trucked to river ports would be trucked to elevators located on rail lines, or to the Tri-Cities area for barge shipment. In Idaho, the number of truck-miles decreases, indicating that rail-based grain elevators are closer than Lewiston. The emission factors from Lee and Casavant (1998) are used in this part of the analysis. Except for Idaho, where haul-back is more common, the emission estimates are doubled to account for containers that return empty. Barge, train, and truck emissions are presented in Table 4-9. The towboat, locomotive, and truck emissions in Table 4-9 account for all commodities and vehicles return trips. The total transportation-related emissions are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	148	130	1,199	34	139

The change in transportation-related emissions, is the difference between the emissions for the Natural River Drawdown Pathway and Existing System (Base Case), and is estimated below:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	45	96	446	18	4

Two data sources are used to estimate transportation-related emissions that are a consequence of the Natural River Drawdown Pathway. The EWITS and Transportation Analysis data result in different emission estimates. The EWITS data suggest that NO_x, PM_{10} and VOC emissions would increase, CO emissions would remain about the same, and SO_2 emissions would decrease. The Transportation Analysis data indicates that CO, NO_x, PM_{10}, and VOC emissions would increase and SO_2 emissions would stay about the same. The average of the two total emission estimates is as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	203	370	1,566	58	174

Table 4-9. Transportation Related Emissions Following Drawdown

Transportation		Emissions (tons)			
Mode	CO	VOC	NO_x	PM_{10}	SO_2
Barge	74	25	544	12	97
Train	65	24	620	16	40
Truck	9	81	35	6	2
Total (TPY)	148	130	1,199	34	139

All transportation-related emissions will continue to decline in the future as fuel efficiencies improve and as national emission standards become effective. Emissions standards for locomotives will take effect in 2000. Emission standards for compression-ignition marine engines are proposed to become effective in 2004. The first phase of a proposed strategy to reduce emissions from heavy-duty vehicles will become effective in 2004.

4.3.2.3 Estimated Vehicle Distribution Resulting From Drawdown

The Natural River Drawdown Pathway would change the distribution of vehicles carrying harvested grain. With drawdown, truck traffic on highways leading to river ports would decrease, and would increase on roads to rail-based elevators and the Tri-Cities area. Modeling estimated the number of grain bushels on eastern Washington roads with and without drawdown (Lee and Casavant, 1998; Jessup and Casavant, 1997). Predicted grain quantities are used to estimate the change in the number of trucks on selected highways, and are combined with WSDOT traffic counts.

Jessup and Casavant (1997) graphically depicted the number of bushels of grain, as a range of values, on eastern Washington roads. The upper range, in millions of bushels, was converted to truck counts at selected locations. The grain volumes and truck counts are presented in Table 4-10. The estimated number of trucks hauling grain has been doubled to account for return trips.

Table 4-10. Change in the Number of Trucks Following Drawdown

Highway	Intersection	With Snake River		Without Snake River		Number of Trucks Per Day			Percent Change
		Millions of Bushels of Grain	Number of Trucks	Millions of Bushels of Grain	Number of Trucks	Current	Change with Drawdown	Projected	
SR 395	SR 26	17	19,615	52.2	60,231	1,925	223	2,148	12
	SR 260	17	19,615	52.2	60,231	2,000	223	2,223	11
SR 127	SR 26	16	18,462	1	1,154	260	(95)	165	(36)
SR 195	SR 26	44.7	51,577	2	2,308	1,173	(270)	903	(23)
SR 26	SR 395	6	6,923	27.2	31,385	336	134	470	40
	SR 261	6	6,923	27.2	31,385	200	134	334	67
	SR 127	16	18,462	27.2	31,385	504	71	575	14
	SR 195	15	17,308	19	21,923	650	25	675	4

The greatest increase in truck counts would take place along SR 395 and SR 26 just before SR 395. Because these roads are already heavily traveled, the increased traffic from grain hauling would account for about 12 percent of the total truck traffic. Truck traffic along highways used to haul grain to river ports would decrease. Truck traffic along some little utilized routes, such as SR 26 near SR 261, would nearly double.

4.3.3 Fugitive Dust

As drawdown proceeds, the reservoir sediments would dry and become subject to wind erosion. The sediments would be seeded as the water recedes. Because large areas of dry sediments would be exposed to wind erosion, the total PM_{10} emissions may be large.

This analysis estimated PM_{10} emissions using EPA methods and 1984 through 1991wind data from Pendleton, Spokane, and Yakima. For each data source, hourly average wind speeds were converted to a value representative of 2-minute speeds just above the sediment surface. A wind speed-dependent emission factor was determined for each hour when the wind speed was greater than the threshold frictional velocity. The hourly emission factors was multiplied by the area of each of the four reservoirs, a particle size multiplier, and a reduction factor to account for mitigation. The hourly emissions were added to form an annual emission estimate for each year of data, each reservoir, and each of the three data sources (Pendleton, Spokane, and Yakima). The three annual emission estimates, Pendleton, Spokane, and Yakima, were averaged. Emission for the four reservoirs were added to form a total average PM_{10} emission rate.

The estimated annual PM_{10} emissions, for the three data sources and the four reservoirs, are presented in Table 4-11. The annual average PM_{10} emissions by reservoir are as follows:

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
TPY	1,555	1,224	1,861	1,652

The Owens Lake study estimated that the annual PM_{10} emissions are from 1.18 million kgs to 3.62 million kgs (130,000 to 400,000 tons) (Section 2.3.2). The Owens Lake emitting area is about 90.65 square kms (35 square miles), resulting in an annual emission rate of about 5,261.7 kgs (5.8 tons) per acre. Once controls are in place, Owens Lake would emit about 0.2 tons per acre. Annual emissions from all four lower Snake River reservoirs, with mitigation measures in place, are estimated to be about 181.4 kgs per hectare (0.2 tons per acre) on an annual basis.

Table 4-11. Annual Windblown PM_{10} Emissions

	Emissions (tons)			
Year	**Ice Harbor**	**Lower Monumental**	**Little Goose**	**Lower Granite**
Pendleton Data				
1984	643	506	770	683
1985	387	304	463	411
1986	317	249	379	336
1987	468	369	561	498
1988	1,372	1,080	1,643	1,458
1989	581	457	695	617
1990	2,212	1,741	2,648	2,351
1991	1,495	1,176	1,790	1,589
Spokane Data				
1984	1,803	1,418	2,158	1,916
1985	2,017	1,587	2,415	2,144
1986	2,002	1,575	2,396	2,127
1987	1,807	1,422	2,163	1,921
1988	3,007	2,366	3,599	3,195
1989	2,857	2,248	3,420	3,036
1990	3,420	2,691	4,094	3,634
1991	1,627	1,280	1,948	1,729

Table 4-11. Annual Windblown PM_{10} Emissions (continued)

	Emissions (tons)			
Year	**Ice Harbor**	**Lower Monumental**	**Little Goose**	**Lower Granite**
Yakima Data				
1984	579	455	693	615
1985	794	625	950	844
1986	723	569	866	769
1987	447	352	535	475
1988	1,522	1,198	1,822	1,617
1990	1,134	892	1,357	1,205
1991	1,231	969	1,474	1,308

Autumn storms that produce fugitive dust from the agricultural areas of eastern Washington would also generate fugitive emissions from the dry lower Snake River reservoirs. The CP^3 program modeled emissions and concentrations from several storms from 1990 to 1993. The November 1990 and October 1991 storms are included in the meteorological database used to generate the reservoir emission estimates. Dry reservoir emissions were estimated by the methods described in Section 3. The CP^3 emissions, using two emission algorithms, and the reservoir emissions, using three data sources, are as follows:

	November 23, 1990		October 21, 1991	
	(tons)	(tons/acre)	(tons)	(tons/acre)
Rangeland, Dry Land, and Irrigated				
CP^3 Emission algorithm	11,905	0.00225	19,070	0.00473
Gillette algorithm	25,022	0.00797	186,621	0.0780
Average	18,464	0.00511	102,846	0.0414
Reservoirs				
Yakima winds	877	0.0259	279	0.00823
Spokane winds	3,880	0.114	606	0.0179
Pendleton winds	0	0	274	0.00808
Average	2,379	0.0468	386	0.00866

Emissions from the reservoirs are 13 and 0.4 percent of the emissions from agricultural lands for the 1990 and 1991 storms, respectively. Both of these storms moved through eastern Washington toward the north. The 1990 storm completely missed the Pendleton area, indicating that individual storms may influence only part of the lower Snake River reservoir system. PM_{10} concentration plots for two 1993 storms, reproduced from Claiborn et al. (1998), are presented in Annex C. These plots indicate that surface PM_{10} concentrations over the Ice Harbor and Lower Monumental reservoirs can be very large, on the order of 2,400 $\mu g/m^3$, during these wind storms.

Measured Kennewick and Spokane PM_{10} concentrations during the 1990 and 1991 storms are available. The average CP^3 and reservoir emissions, and measured 24-hour PM_{10} concentrations are as follows:

	November 23, 1990	October 21, 1991
Average CP^3 and reservoir emissions (tons/acre)	0.0035	0.0430
Average total reservoir emissions (tons/acre)	0.0468	0.0087
24-hour measured PM_{10} concentrations ($\mu g/m^3$)		
Kennewick site	126	1,035
Spokane (industrial site)	-	351
Spokane (residential site)	251	267

For both storms, the duration of high wind speeds was greatest in Spokane, and the winds were more intense in Spokane. Average hourly wind conditions, including the number of consecutive hours that the hourly average wind speed remained above the threshold frictional velocity, are as follows:

	November 23, 1990	October 21, 1991
Yakima		
• Average wind speed (mph)	26	27
• Maximum wind speed	32	32
• Duration (hours)	20	6
Spokane		
• Average wind speed (mph)	27	26
• Maximum wind speed	35	38
• Duration (hours)	82	15
Pendleton		
• Average wind speed (mph)	-	25
• Maximum wind speed	-	35
• Duration (hours)	-	7

The reservoir emission estimates are conservative. Individual wind storms impact only a portion of the lower Snake River region, whereas the emission estimates assume that all reservoirs are subject to the same wind conditions. It is interesting to note that the threshold frictional velocities of dryland soils with residue, rangelands, some dryland fallow soils, and some irrigated soils are higher than the dry reservoir sediments.

The meteorological database may be used to determine the expected number of wind storms that could produce fugitive emissions and the relative magnitude of the emissions during each storm. The frequency of occurrence of emissions, 907.2-kg (in 100-ton) increments, was determined for all four reservoirs by meteorological data source. The data indicate that nearly all of the storms produced total PM_{10} emissions less than about 181,440 kgs (200 tons) per event (Figure 4-1) from all four reservoirs, which is equivalent to about 5.44 kgs per hectare (0.006 ton per acre).

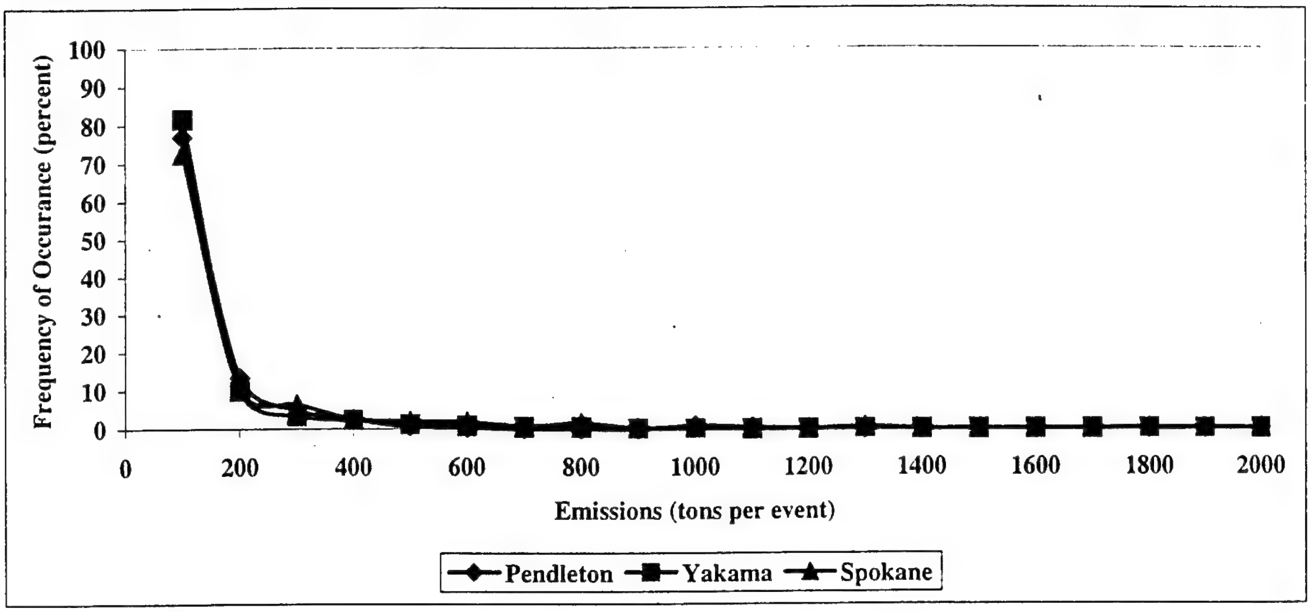

Figure 4-1. Frequency of Occurrence of Predicted Emissions for Individual Wind Events

The results presented above are conservative. Field studies have indicated that about three hours of high wind speeds from the same direction are required to initiate windblown dust (Environalysis, 1996). Furthermore, winds producing fugitive dust in one region of the lower Snake River would not impact the entire river basin. The Revegetation Plan (Appendix D) calls for seeding the sediments as the water recedes, and restricting access to the dry reservoirs, thereby minimizing the amount of available erodible material. This analysis assumed that mitigation efforts would reduce emissions by 90 percent. Field studies at Owens Lake in California indicate that a 99 percent reduction is soil erosion and PM_{10} emissions is possible with a salt grass cover of 50 percent (Great Basin Unified Air Pollution Control District, 1998). Similar reductions for the dry lower Snake River reservoirs are expected.

Rain often accompanies strong winds. This analysis did not screen out occasions of precipitation with strong winds, but it did reduce the annual emission estimates to account for the average number of days of precipitation.

The population most susceptible to windblown dust from exposed sediments would be residences along the river. Because the Snake River valley would channel the winds, residences located where the river bends would be most susceptible to windblown dust.

Recent studies focused on identifying potential impacts associated with erosion, suspension, and transport of sediments resulting from increased river flows during drawdown. From characterization of sediment samples, summarized in Technical Appendix C (Water Quality), manganese, dioxin (and its constituents), and total DDT (and its constituents) were identified as contaminants of concern. Based on sediment and water quality criteria, areas of concern exist in all four reservoirs. However, these areas may or may not be of concern from an air quality perspective. The following additional work is required before the potential airborne concentrations of these pollutants can be estimated:

- Characterize the surface concentrations of the sediments that would be subject to wind erosion (not the average of the upper 0.6096 m (2 feet) of sediment, as reported by Appendix C).
- Determine the horizontal extent of the contaminants.
- Estimate 24-hour and annual emissions of hazardous and toxic air pollutants.
- Perform dispersion modeling for those pollutants emitted in significant quantities to determine if people living near the reservoirs are at risk.

4.3.4 Emissions

The Technical Report on Hydropower Costs and Benefits (DREW, 1999a) evaluated the costs associated with replacing power generated by the lower Snake River hydropower facilities, and concluded that it is not necessary to replace all 3,500 MW of hydropower capacity. The most likely scenario with dam breaching is construction of 1,550 MW of generating capacity somewhere in the Pacific Northwest by 2010. This future replacement case, referred to as A3 (Natural River Drawdown), was used to evaluate emission impacts. PROSYM model predictions for A3 represent 2010 emissions from:

- All generating units in the WCSS
- Natural gas fired combined cycle units that will be constructed regardless of the fate of the Snake River hydrofacilities, to meet growth in the demand for electricity
- 1,550 MW of replacement power.

Predicted emissions, in units of thousands of tons, are presented by fuel type in Table 4-12 for the 1,550 MW of replacement capacity scenario. The total power generating emissions following drawdown are:

Pollutant	**CO**	**CO_2**	**NO_x**	**PM_{10}**	**SO_2**	**VOC**	**Benzene**	**Formaldehyde**
1000 TPY	408	418,420	58	49	459	1	0.004	0.04

The assumptions for this analysis are the same as those presented earlier. The new power plants are combined cycle natural gas units. Several of the IPPs, with mostly natural gas plants, also include a few coal-fired units in their generating inventory. Emissions of CO, PM_{10}, SO_2, VOCs, benzene, and formaldehyde assume that these IPPs are all natural gas fired units. EPA emission factors were used to determine pollutants other than CO_2, NO_x, and SO_2. Actual emissions could vary because of different control strategies for the other pollutants.

In the 7-year period from 1990 to 1997, U.S. CO_2 emissions increased from 4.9 million to 5.4 million kgs (5,433 to 6,014 million tons). This represents an increase of about 11 percent (EPA, 1999). If GHG emission rates continue to increase at the same rate, national CO_2 emissions in 2011 will be about 6.7 million kgs (7,367 million tons). The 2010 power plant CO_2 emissions presented above may be compared to the projected national emissions. Western U.S. electric utility CO_2 emissions following drawdown would represent 5.7 percent of the national CO_2 emissions.

Table 4-12. Power Generating Emissions for the A3 Case (Natural River Drawdown), with 1,550 MW of Replacement Capacity

	Emissions (thousands of tons)							
Generation Resource	**CO**	**CO_2**[1/]	**NO_x**[1/]	**PM_{10}**	**SO_2**[1/]	**VOC**	**Benzene**	**Formaldehyde**
Coal								
Arizona/New Mexico	76	77,957	16	19	173	0.2	0.001	0.0002
Canada	45	46,060	8	8	75	0.1	0.0007	0.0001
Northwest	12	12,522	2	4	41	0.04	0.0002	0.00004
Rocky Mountains	117	120,144	24	18	165	0.3	0.002	0.0003
Fuel Oil								
FO #2	0.3	1,098	0.04	0.004	0.4	0.001	-	0.00008
FO #6	0.01	36	0.003	0.0003	0.1	0.00007	-	0.000006
Natural Gas								
Alberta	0.2	190	0.002	0.0002	0.02	0.0001	-	0.00001
Arizona/New Mexico	5	4,844	0.7	0.07	0.03	0.04	-	0.004
British Columbia	0.3	304	0.004	0.0003	0.003	0.0002	-	0.00002
Future Combined Cycle	91	92,713	2	0.2	0.6	0.1	-	0.01
Northern California	10	10,583	0.8	0.08	0.07	0.04	-	0.005
PG&E IPPs	13	12,792	1	0.1	1	0.06	-	0.006
Pacific Northwest	9	8,926	0.2	0.02	0.06	0.009	-	0.001
Rocky Mountains	3	3,154	0.4	0.04	0.02	0.02	-	0.003
Rocky Mountains/Colorado	2	1,905	0.1	0.01	0.01	0.006	-	0.0006
Southern California	12	12,710	0.6	0.06	0.09	0.03	-	0.004
SCE IPPs	12	11,728	1	0.1	3	0.06	-	0.007
SDG&E IPPs	0.7	752	0.07	0.006	0.005	0.004	-	0.0004
Total System Emissions	408	418,421	58	49	459	1	0.004	0.04

1/ Source: DREW, 1999a.

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The change in power generating emissions, following drawdown is the difference in the values presented in Tables 23 and 30. The changes in emissions are presented in Table 4-13. Table 4-13 indicates that CO and CO_2 emissions are predicted to increase by 3.8 million and 38 million kgs per year (4,134 and 4,186,804 TPY), respectively. About 65 percent of this increase would be from the new combined cycle plants. This increase in CO_2 emissions would be only about 0.1 percent of the projected U.S. CO_2 emissions.

SO_2 emissions are predicted to increase by about 1.5 million kgs per year (1,645 TPY) above the existing System Case, mostly as a result of an increase in northwest coal plants. NO_x, PM_{10}, VOCs, benzene, and formaldehyde are predicted to increase because of northwest coal and natural gas combustion. Emissions from the combustion of Alberta, Arizona, and New Mexico coal, and emissions from some of the California IPPs, are predicted to decrease.

The analysis indicates that total emissions throughout the WCSS region would increase from 0.005 to 1.0 percent, for all pollutants. Increases in emissions above the base case, in percent, are as follows:

Pollutant	CO	CO_2	NO_x	PM_{10}	SO_2	VOC	Benzene	Formaldehyde
Percent	1.0	1.0	0.3	0.4	0.4	0.2	0.4	0.005

Construction of new power plants in Oregon and Washington is continuing. Additional power plants would be required with Natural River Drawdown Pathway. The Power System Analysis has estimated emissions for 1,550 MW of replacement power.

An estimate of where new power plants may be located is useful to the analysis. The hydropower study team, after reviewing studies conducted by the Power Planning Council and consulting the transmission experts at BPA, concluded that the following locations are the most favorable to meet power demand and transmission reliability needs:

Location	Number of Combined Cycle Plants	Approximate Size of Individual Plants
Tri-Cities area, Washington	2	250 MW
Hermiston, Oregon	1	250 MW
Puget Sound area, Washington	3	250 MW

In the deregulated power industry, the new power plants would be privately owned. The above locations represent the best locations from a systems approach. Because the actual site would be decided by market conditions, it was projected for this study that power producers would build plants at these locations. However, there is a high degree of uncertainty regarding specific siting and timing of plant construction. Design characteristics of these plants will not be available for a number of years.

The most predominant type of thermal power plant recently added to the west coast power system has been natural gas-fired combined-cycle combustion turbine plants (DREW, 1999a). Nine of these types of power plants have been constructed in Oregon and Washington since 1991, and another seven are planned. The Power System Analysis concluded that these plants represent the most cost-effective new additions over a wide range of economic and environmental factors. Because of their low cost, abundance of suitable sites, and favorable technical and environmental

Table 4-13. Change in Power Generating Emissions—Natural River Drawdown with 1,550 MW of Replacement Capacity Minus Existing System

	Emissions (thousands of tons)							
Generation Resource	**CO**	**CO_2 1/**	**NO_x 1/**	**PM_{10}**	**SO_2 1/**	**VOC**	**Benzene**	**Formaldehyde**
Coal								
Arizona/New Mexico	0.004	5	0.004	(0.002)	(0.02)	0.00005	0.0000003	0.00000005
Canada	0.1	145	0.03	0.03	0.3	0.0004	0.000002	0.0000004
Northwest	0.4	375	0.08	0.1	1	0.001	0.000006	0.000001
Rocky Mountains	0.3	319	0.06	0.03	0.3	0.0009	0.000005	0.0000009
Fuel Oil								
FO #2	(0.01)	(44)	(0.0009)	(0.00008)	(0.02)	(0.0002)	-	(0.000002)
FO #6	(0.0003)	(1)	0.0	0.0	(0.02)	0.0	-	0.0
Natural Gas								
Alberta	(0.02)	(23)	(0.001)	(0.0001)	(0.0004)	(0.00005)	-	(0.000006)
Arizona/New Mexico	(0.2)	(156)	(0.03)	(0.003)	(0.0008)	(0.002)	-	(0.0002)
British Columbia	(0.05)	(54)	(0.0004)	0.0	0.0	(0.00002)	-	(0.000002)
Future Combined Cycle	4	4,456	0.1	0.01	0.03	0.006	-	0.0006
Northern California	(0.4)	(364)	(0.03)	(0.003)	(0.002)	(0.002)	-	(0.0002)
PG&E IPPs	(0.2)	(168)	(0.01)	(0.001)	(0.0008)	(0.0006)	-	(0.00007)
Pacific Northwest	0.07	70	0.0009	0.000	0.001	0.00005	-	0.000006
Rocky Mountains	(0.05)	(46)	(0.008)	(0.0008)	(0.0001)	(0.0004)	-	(0.00005)
Rocky Mountains/Colorado	(0.02)	(18)	(0.001)	(0.0001)	(0.0004)	(0.00007)	-	(0.000008)
Southern California	(0.3)	(277)	(0.016)	(0.002)	(0.003)	(0.0009)	-	(0.0001)
SCE IPPs	(0.03)	(30)	(0.003)	(0.0003)	0.0006	(0.0002)	-	(0.00002)
SDG&E IPPs	(0.001)	(1)	0.0	0.0	0.0	0.0	-	0.0
Total System Emissions	4	4,187	0.2	0.2	2	0.003	0.00001	0.000002

1/ Source: DREW, 1999a. 1/

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characteristics, natural gas-fired combined-cycle power plants are the most likely plants to be built in the near future.

Replacement power plants would likely share many of the characteristics of recently constructed and planned power plants. The plants have one or more natural gas fired combustion turbines that power electrical generators. Heat from the turbine exhaust is used to generate steam in a heat recovery steam generator (HRSG). Additional electricity is produced by a steam turbine. Many of the recent power plants are cogeneration projects that provide steam to a host. A survey of recent air discharge permit applications for power plants was completed for this study. The characteristics of 16 recently constructed or proposed power plants are presented in Table 4-14. Most of these plants have two units, and the average output from the plants is about 340 MW.

Table 4-14. Characteristics of Recent Power Plants in the Pacific Northwest

Generic Facility Designation	Location	Year Permitted or Constructed	Number of Units	Total MW	Host
Plant 1	Chehalis, WA	(1)	2	620	Yes
Plant 2	Goldendale, WA	(1)	2	214	No
Plant 3	Boardman, OR	1995	2	504	Yes
Plant 4	Bellingham, WA	1991	3	243	Yes
Plant 5	Hermiston, OR	1993 (2)	2	476	Yes
Plant 6	Hermiston, OR	1998 (2)	2	548	No
Plant 7	Klamath, OR	1996 (2)	1	305	Yes
Plant 8	Bingen, WA	1998	1	63	Yes
Plant 9	Longview, WA	1996	1	96	Yes
Plant 10	Anacortes, WA	1993	3	140	Yes
Plant 11	Creston, WA	(1)	4	714	No
Plant 12	Vancouver, WA	1997	1	248	No
Plant 13	Satsop, WA	(1)	2	454	No
Plant 14	Sumas, WA			120	Yes
Plant 15	Sumas, WA	(1)	3	507	No
Plant 16	Ferndale, WA		2	245	Yes

Notes: (1) Not yet constructed
(2) Application submitted

Emissions from the combined-cycle power plants are controlled through several technologies. Steam or water is injected into combustion chambers to control NO_x emissions. Further NO_x control is obtained with the use of low NO_x burners. Selective catalytic reduction (SCR), using ammonia injection, further reduces NO_x emissions. CO emissions are controlled with good combustion and sometimes with SCR technology. PM_{10} and SO_2 emissions are controlled by use of a clean fuel such as natural gas.

Combined-cycle power plants have other emission sources. Depending on the design, the plants may have duct burners and auxiliary boilers. Emissions from these other sources are small compared to the combustion turbines. Several of the plants have the ability to fire with fuel oil for

short periods during natural gas curtailment. Fuel oil firing is the source of most of the PM_{10} and SO_2 emissions. Total predicted plant emissions and predicted average emission rate are presented by pollutant in Table 4-15. All emissions estimates presented are taken from recent permit applications to regional air quality permit agencies.

Table 4-15. Predicted Total Facility Emissions From Northwest Combined-Cycle Power Plants

	Emissions							
Generic Facility Designation	**Units (in 1000's)**	**CO**	**NO_x**	**PM_{10}**	**SO_2**	**VOC**	**Ammonia**	**Formaldehyde**
Plant 1	TPY	436	313	42	83	64	201	18
Plant 2	TPY	146	188	36	16		94	25
Plant 3	TPY	439	520	78	10	26	107	0.5
Plant 4	TPY	131	174	56	43		80	1
Plant 5	TPY	403	245	70		31		
Plant 6	TPY	734	134	142	2	26		
Plant 7	TPY	223	187	55	48	50		
Plant 8	TPY	61	71	18	11	50	71	0.4
Plant 9	TPY	88	84	23	1		45	0.3
Plant 10	TPY	132	412	33	7			1
Plant 11	TPY	1,174	876	151	17			0.4
Plant 12	TPY	88	99					
Plant 13	TPY	271	431	114	53			
Plant 14	TPY							
Plant 15	TPY	378	767	118	13			1
Plant 16	TPY							
Average	TPY	336	322	72	25	41	100	5

Source: Authority to construct permit applications and notice of findings documents for projects, available from the following agencies: Northwest Air Pollution Authority, Southwest Air Pollution Control Authority, State of Washington Department of Ecology, State of Oregon Department of Environmental Quality, and United States Environmental Protection Agency, Region X.

Ambient concentrations resulting from the power plant emissions were predicted as part of the air quality permitting process. These predicted concentrations are presented in Table 4-16, along with the most stringent DEQ or Ecology AAQS. The largest predicted concentrations are reported in Table 4-16. The standards for hazardous and carcinogenic air pollutants are obtained from Ecology regulations for toxic air pollutants (WAC 173-460). The ammonia standard is a threshold ambient concentration for hazardous substances that will protect public health. The formaldehyde standard is a risk-based concentration that will result in a cancer risk of less than one in one million. The standards for hazardous and toxic air pollutants are applied at the location of the exposure and not the location of the maximum concentration. All predicted concentrations resulting from the power plants are less than the AAQS.

Plants 1, 5, and 13 have gone through the permitting process and are available for construction if additional generating resources are required. It is presumed that if the lower Snake River hydrofacilities are removed, these resources would be constructed, if they have not already been built.

Table 4-16. Predicted Concentrations Resulting from Power Plant Emissions

	Concentrations (µg/m^3)										
	CO		NO_x	PM_{10}		SO_2				Ammonia	Formaldehyde
Generic Facility Designation	8-hr	1-hr	Annual	Annual	24-hr	Annual	24-hr	3-hr	1-hr	24-hr	Annual
Most stringent AAQS	10,000	40,000	100	50	150	53$^{(1)}$	260$^{(1)}$	1,300	1,048$^{(1)}$	100$^{(2)}$	0.077$^{(2)}$
Plant 1	152.7	295.2	3.5	0.7	5.0	1.3	23.8	90.1	105.6	5.5	0.077
Plant 2	114.0		4.1	0.8	7.1					13.9	0.560
Plant 3	32.3		2.8	0.5						1.8	
Plant 4	42.0	59.0	1.9	0.4	7.1					59.2	0.014
Plant 5	500.0				1.0		5.0				
Plant 6	500.0		1.0		1.0		5.0				
Plant 7	5.1		2.8	26.2		12.5					
Plant 8	18.9		3.1	0.8		0.4				12.5	0.016
Plant 9	14.7		0.4	0.1						0.2	0.001
Plant 10	0.04		1.4	0.2		0.03					0.004
Plant 11	68.0		1.6	0.3							0.031
Plant 12											
Plant 13	15.8	23.0	0.2	0.04	2.2	0.0	2.4	21.0	24.1	0.7	0.007
Plant 14											
Plant 15	23.0		1.8	0.03		0.03					0.013
Plant 16											

Notes: (1) Standards of the Oregon Department of Environmental Quality and State of Washington Department of Ecology
(2) Risk based standards for hazardous and toxic air pollutants, from WAC 173-460

Source: Authority to construct permit applications and notice of findings documents for projects, available from the following agencies: Northwest Air Pollution Authority, Southwest Air Pollution Control Authority, State of Washington Department of Ecology, State of Oregon Department of Environmental Quality, and United States Environmental Protection Agency, Region X.

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5. Comparison of Pathways

This section presents a comparison of the atmospheric emissions estimated for the Existing System (Base Case), Major System Improvements, and Natural River Drawdown Pathways, and includes a brief discussion of potential mitigative measures, cumulative effects, and unavoidable adverse effects.

This analysis estimated criteria air pollutants and TAP emissions for the Existing System (Base Case), Major System Improvements, and Natural River Drawdown Pathways. The air quality issues related to the Lower Snake River Juvenile Salmon Migration Feasibility Study are:

- Fugitive dust emissions resulting from deconstruction of the dams
- The change in the quantity and distribution of vehicle emissions as commodities are shifted from barge to truck and rail
- Fugitive dust emissions resulting from dry exposed lake sediments during high wind speed events
- Atmospheric emissions associated with replacement power generation by thermal power plants.

Estimated air quality impacts are presented below by alternative. Cumulative effects, mitigation measures, unavoidable adverse effects, and incomplete information are also discussed below.

5.1 Summary of Emissions by Pathway

Emissions estimated in Section 4 are summarized in Table 5-1. Emission increases above those estimated for the Existing System (Base Case) are presented in Table 5-1 for the Major System Improvements and Natural River Drawdown Pathways. Transportation-related emissions are an average of the estimates produced from the EWITS and Transportation Analysis data.

5.2 Existing System (Base Case)

5.2.1 Direct and Indirect Effects

No emission increases are estimated for the Existing System (Base Case), which represents current conditions projected to 2010. Therefore, this alternative would have no direct or indirect air quality effects. Under this alternative, Snake River barge traffic would continue, and new power plants would continue to be built as power demand increases. Emissions from these new plants have been factored into the analysis.

5.2.2 Cumulative Effects

There are no cumulative effects for the Existing System (Base Case).

5.2.3 Mitigation Measures

No mitigation measures are required for the Existing System (Base Case). New power plants would be subject to NSR, including BACT and a proposed NESHAP. New power plant emissions would be regulated by local, state, and Federal air quality control programs. Transportation-related emissions would be subject to proposed emission standards.

Table 5-1. Summary of Emissions in Tons

	Emissions (Tons)							
	CO	**CO_2**	**NO_x**	**PM_{10}**	**SO_2**	**VOC**	**Benzene**	**Formaldehyde**
Existing System (Base Case) Pathway								
Demolition								
Transportation	218		1,586	49	245	280		
Windblown Dust								
Power Generation	403,624	414,233,886	57,757	49,267	457,383	1,132	4	45
Total	**403,842**	**414,233,886**	**59,343**	**49,317**	**457,628**	**1,411**	**4**	**45**
Major System Improvements Pathway								
Construction				1				
Transportation	218		1,586	49	245	280		
Windblown Dust								
Power Generation	403,624	414,233,886	57,757	49,267	457,383	1,132	4	45
Total	**403,842**	**414,233,886**	**59,343**	**49,318**	**457,628**	**1,411**	**4**	**45**
Change	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Natural River Drawdown Pathway								
Demolition				304				
Transportation	203		1,566	58	174	370		
Windblown Dust			57,931	6,292				
Power Generation	407,758	418,420,690	58,031	49,463	459,196	1,134	4	45
Total	**407,961**	**418,420,690**	**59,497**	**56,118**	**459,370**	**1,505**	**4**	**45**
Change	**4,119**	**4,186,804**	**154**	**6,801**	**1,742**	**93**		

5.2.4 Unavoidable Adverse Effects

Emissions from new power plants would result in an increase in air emissions.

5.2.5 Incomplete Information

The power system models have indicated the need for additional power generation capacity. The analysis assumes that additional capacity would be met through combined-cycle natural-gas turbines. Design data for these facilities, including the location, size, and other specifications, would not be available until firm proposals for the projects are in place. Demand for additional power may be met through non-thermal power plants.

5.3 Major System Improvements Pathway

5.3.1 Direct and Indirect Effects

Minor construction-related emission increases are anticipated for the Major System Improvements Pathway. Therefore, only minor direct or indirect air quality effects would result. As with the Existing System (Base Case), Snake River barge traffic would continue, and new power plants would continue to be built as power demand increases. Emission estimates for these new plants are identical to those of the Existing System (Base Case).

5.3.2 Cumulative Effects

There are no cumulative effects for the Major System Improvements Pathway.

5.3.3 Mitigation Measures

No mitigation measures are required for the Major System Improvements Pathway. New power plants would be subject to NSR, including BACT and a proposed NESHAP. Emissions from new power plants would be regulated by local, state, and Federal air quality control programs. Transportation-related emissions would be subject to proposed emission standards.

5.3.4 Unavoidable Adverse Effects

Emissions from new power plants would result in an increase in air emissions.

5.3.5 Incomplete Information

The power system models have indicated the need for additional power generation capacity. The analysis assumes that additional capacity would be met through combined-cycle natural-gas turbines. Design data for these facilities, including the location, size, and other specifications, will not be available until firm proposals for the projects are in place. Demand for additional power may be met through non-thermal power plants.

5.4 Natural River Drawdown Pathway

5.4.1 Direct and Indirect Effects

The Natural River Drawdown Pathway would result in demolition fugitive emissions (PM_{10}), emissions associated with the loss of barge transportation (criteria air pollutants), fugitive dust from exposed reservoir sediments, and emissions associated with replacement power generation

(criteria air pollutants, HAPs, and GHGs). Deconstruction emission estimates do not include emissions associated with reservoir modifications. The transportation-related emission estimates do not consider tire and brake emissions.

5.4.2 Cumulative Effects

The magnitude of the cumulative effects depends on the dam breaching schedule and the construction schedule for replacement power plants. Maximum emissions would occur if all four dams were breached at once, as is assumed for the emission estimates. In this scenario, the deconstruction and fugitive windblown emissions would occur in the same year. The increase in transportation and power generating emissions would take place as the commerce and power systems adjust to the loss of the lower Snake River facilities and new thermal power plants come online.

Emissions associated with increases in truck and rail transportation would be distributed in five states (Idaho, Montana, Washington, Oregon, and North Dakota). Most of the emission increases would be in southeastern Washington. The greatest increase in truck traffic would take place along State Route 395 leading into the Tri-Cities area.

The most likely locations for replacement power plants are in the Hermiston area and along the Interstate corridor in Washington and Oregon. Emissions associated with replacement power would affect the entire WCSS, covering the western United States. Emissions for older coal and oil-fired power plants may actually decrease.

5.4.3 Mitigation Measures

Deconstruction of the dams would incorporate standard construction practices to suppress fugitive dust, such as spraying haul roads with water. Some of the dam core material would be saturated with water, reducing the potential for fugitive dust emissions. Deconstruction of the Snake River dams would most likely not take place in a single year.

Vehicles will continue to experience efficiency improvements and associated reductions in emissions.

Appendix D, Natural River Drawdown Engineering, calls for revegetation to be conducted in phases as the water recedes. In addition, access to the dry lakebed would be restricted, further reducing the availability of erodible material. The analysis assumes that dry sediments are disturbed between high wind-speed events, thereby providing additional erodible material. The emission estimates for windblown dust may be overestimated.

Deconstruction of the Snake River dams would most likely not take place in a single year. The greatest fugitive dust emissions would not take place at the same time, as has been estimated.

New power plants would be subject to NSR, BACT, and possibly a new NESHAP. Emissions from new power plants may be lower than estimated. The new power plants would be located throughout the western United States.

5.4.4 Unavoidable Adverse Effects

If the lower Snake River dams are breached, deconstruction, transportation, fugitive, and power plant emissions would take place.

Deconstruction – Breaching of the dams would resemble a large construction project. Deconstruction of the dams would probably take several years and/or would be staged, resulting in lower emissions per year.

Transportation – Emissions of CO NO_x and SO_2 would decline by 1 to 30 percent. Emissions of PM_{10} and VOCs would increase by 20 to 30 percent above the Existing System Pathway emissions. Truck traffic on SR 392 would increase by as many as 220 trucks per day (in both directions). The number of trucks on SR 195 at SR 26 would decrease by 270 trucks per day.

Fugitive Dust – Storms would generate fugitive emissions from agricultural lands and, until the vegetation cover becomes established, the dry lake sediments. Emissions from the dry reservoirs would be between 0.4 and 13 percent of the total emissions from eastern Washington agricultural areas during individual wind storms. The resulting ambient concentrations may be a problem, especially if the surface sediments are contaminated.

Power Plants – Emissions of criteria air pollutants, HAPs, and GHGs would increase by 1 percent or less above the Existing System Pathway emissions. Western utility CO_2 emissions would be 6 percent of the national CO_2 emissions by 2010. CO_2 emissions from replacement power plants would by 0.06 percent of the national CO_2 emissions.

5.4.5 Areas of Possible Future Study

The emission calculations used available data and reasonable values for preliminary information. Because of information gaps, the emissions are considered as estimates for comparison of the alternatives. Furthermore, the preliminary data are used to predict ambient concentrations resulting from deconstruction, transportation, fugitive dust, and power-related emissions. Future studies may include the following:

- HAP emission factors for vehicles and other HAP emission factors for power plants
- Details necessary for more precise deconstruction emission estimates, including a construction schedule, moisture and silt content of excavated material and haul roads, area of stockpiles, length of haul roads, and distance to critical receptors
- Ambient PM_{10} concentrations resulting from deconstruction emissions
- Details necessary for precise estimates of transportation-related emissions resulting from deconstruction, including 1) revised emission factors for towboats, locomotives, and trucks; 2) a more precise estimate of the number of tow boats and the number of miles (or hours) traveled in the Snake and Columbia rivers; 3) a more precise estimate of the number of vehicles on state and county roads expected to experience the greatest increases in truck traffic; and 4) a more precise estimate of the number of trains on railroads expected to experience increased train traffic
- Ambient concentrations resulting from increases in truck and locomotive traffic arising from the Natural River Pathway, including an analysis of conformity and ambient concentrations adjacent to highways and railroads that would be most impacted
- Details necessary for more precise emission estimates for windblown fugitive dust, including additional maps of the reservoir topography, distribution of fine material within the reservoirs, onsite wind conditions, location, concentration, and extent of sediment contaminants, and location of sensitive receptors

- Ambient PM_{10} concentrations resulting from windblown dry lake sediments, including an analysis of conformity and ambient concentrations adjacent to the reservoirs to define current conditions
- Details necessary for more precise estimates of emissions from new power plants, including the size and precise location of the plants, number of units, proposed fuel, design data for exhaust stacks, location of property boundaries, critical receptors, and the regulatory environment
- Ambient concentrations of criteria and hazardous air pollutants resulting from power plant emissions, including cumulative impacts and air-quality-related values in protected areas
- Transportation modeling for all waterborne commerce, not just the wheat and barley harvest, incorporating haulback trips and return trips of empty containers
- Other economic effects that may influence the transportation analysis, such as higher transportation costs and limited transportation capacity
- The magnitude and extent of any hazardous contaminants in reservoir sediments.

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7. Glossary

Air pollutants: Pollutants that are anthropogenically added to the atmosphere and cause a deviation from the natural composition of the air. Generally referred to as criteria air pollutants.

Air quality: The condition of the atmosphere that would ensure that public health and public welfare would be protected.

Ambient air quality standards (AAQSs): Standards required by the Federal Clean Air Act, and enforced by the U.S. Environmental Protection Agency, state, and local air quality regulatory agencies, that protect public health, provide for the most sensitive individuals, and allow a margin of safety by setting an acceptable level for measured pollutant concentrations. AAQSs cannot take into account the cost of achieving the standards.

Area sources: Large areas where air pollutants are emitted directly to the atmosphere, such as roads and agricultural fields.

Best Available Control Technology: An emission limitation based on the maximum degree of reduction for each air pollutants, considering energy, environmental, and economic impacts.

Bushel-mile: This energy- or emissions-related value expresses the transportation of a bushel of grain a distance of one mile.

Climate: A long-term aggregate of atmospheric conditions involving heat, moisture, and air movement.

Combined-cycle combustion turbines: Electricity producing plant that employs a combustion turbine, a heat recovery steam generator, and a steam turbine.

Concentration: Mass concentration is the amount of a pollutant found in a given volume of air. Concentration by volume refers to the number of pollutant molecules per million or billion air molecules.

Criteria air pollutants: Air pollutants for which ambient air quality standards have been established, including carbon monoxide, lead, particulate matter, nitrogen dioxide, ozone, and sulfur dioxide.

Drawdown Regional Economic Workgroup (DREW): A group of regional economists studying the economic issues associated with alternative actions on the lower Snake River.

Drawdown: In the context of this FR/EIS, drawdown means returning the lower Snake River to its natural, free-flowing condition via dam breaching.

Emission factor: A parameter that relates atmospheric emissions to other quantities such as fuel consumption, industrial production rates, road miles, or wind speed.

Emission: The direct release of a pollutant into the air. This analysis does not consider natural emissions such as volcanic eruptions and pollen.

Fastest mile: A wind speed corresponding to a mile of wind movement past a measurement location in the least amount of time.

Fugitive dust: Particulate matter made airborne by the wind, human activity, or both, and not released to the atmosphere through a control device such as a stack or vent.

Greenhouse gases: Air pollutants and air constituents that enhance atmospheric heat retention. Greenhouse gases include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, partially halogenated fluorocarbons, ozone, and water.

Hazardous air pollutants: Toxic or carcinogenic emissions. Hazardous air pollutants are listed in Section 112 of the Clean Air Act.

Hydropower: Electricity generated by turbines spun by the power of falling water.

Megawatt (MW): One million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Meteorology: The day-to-day or hour-to-hour condition of the atmosphere. Uses physical processes to interpret and explain atmospheric processes.

Mitigation: To moderate or compensate for an impact or effect.

Nonattainment areas: Geographic areas with measured pollutant concentrations greater than the AAQSs.

Peak gust: The maximum wind speed during extremely brief time intervals (one or two seconds).

Plume rise: Elevation of a plume gained from vertical velocity and/or buoyancy. Plume rise plus stack height is the effective plume height.

Point sources: Localized emission sources such as smoke stacks and other industrial sources.

Precipitation: Water in liquid or solid form (rain, drizzle, snow, hail) falling to the earth.

Relative humidity: The ratio of the amount of water vapor in the air to the amount the air could hold at a given temperature and pressure.

Stability: Condition of the atmosphere that influences vertical motion of air. Unstable conditions encourage vertical motion in both directions. Stable conditions discourage vertical motions. Neutral conditions neither encourage nor discourage vertical motion.

Surface bypass collection (SBC) system: System designed to divert fish at the surface before they have to dive and encounter the existing turbine intake screens. SBCs direct the juvenile fish into the forebay, where they are passed downstream either through the dam spillway or via the juvenile fish transportation system of barges and trucks.

Surface roughness: A distance that is proportional to the dimension of objects penetrating the surface. A low surface roughness characterizes smooth surfaces.

Threshold frictional velocity: The minimum wind speed required to begin to move erodable surface particles.

Ton-mile: An energy- or emissions-related value that expresses the transportation of one ton of a commodity a distance of one mile.

Vehicle emissions: Generally, tailpipe emissions resulting from combustion. Can also refer to tire, brake pad, and roadway wear.

Volatile organic compounds (VOC): Any organic compound, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

Wind erosion: Removal of surface particles by the action of wind.

Wind rose: Depicts the joint frequency of occurrence, in percent, of wind speed and wind direction categories, for a particular location and time period. The radials of the wind rose indicate the direction from which the wind is blowing. The length of the radials indicates the frequency of occurrence for that direction. The width of the radials indicate the wind speed class.

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ANNEX A

SUPPLEMENTAL CLIMATOLOGY DATA

Source: National Climatic Data Center

NORMALS, MEANS, AND EXTREMES

PENDLETON, OR (PDT)

LATITUDE:	LONGITUDE:	ELEVATION (FT):		TIME ZONE:	WBAN: 24155
45° 41' 54" N	118° 50' 03" W	GRND: 1482	BARO: 1507	PACIFIC (UTC+ 8)	

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	39.7	46.9	54.2	61.3	70.0	79.5	87.8	86.2	76.3	63.7	48.9	40.5	62.9
	MEAN DAILY MAXIMUM	50	39.3	46.2	53.6	61.5	70.2	78.6	87.6	85.7	76.7	63.5	48.8	40.9	62.7
	HIGHEST DAILY MAXIMUM	62	70	75	79	91	100	108	110	113	102	92	77	67	113
	YEAR OF OCCURRENCE		1995	1996	1964	1977	1986	1961	1939	1961	1955	1980	1975	1980	AUG 1961
	MEAN OF EXTREME MAXS.	50	58.5	62.3	68.2	77.5	88.0	94.6	101.2	99.5	92.4	80.1	65.7	59.5	79.0
	NORMAL DAILY MINIMUM	30	27.2	31.6	35.4	39.4	45.8	52.9	58.0	57.7	49.9	41.0	34.1	27.9	41.7
	MEAN DAILY MINIMUM	50	26.3	30.8	34.8	39.6	46.1	52.5	57.9	57.4	50.2	41.1	33.6	28.4	41.6
	LOWEST DAILY MINIMUM	62	-22	-18	1	18	25	35	42	40	30	11	-12	-19	-22
	YEAR OF OCCURRENCE		1957	1950	1993	1936	1954	1991	1971	1980	1970	1935	1985	1983	JAN 1957
	MEAN OF EXTREME MINS.	50	6.3	14.3	23.6	30.2	35.3	42.4	47.9	47.6	38.9	29.1	20.3	11.5	28.9
	NORMAL DRY BULB	30	33.5	39.2	44.8	50.3	57.9	66.2	72.9	72.0	63.1	52.4	41.5	34.3	52.3
	MEAN DRY BULB	50	32.7	38.5	44.2	50.6	58.1	65.6	72.8	71.5	63.5	52.3	41.2	34.6	52.1
	MEAN WET BULB	14	31.3	33.6	39.6	44.4	49.3	53.4	56.5	55.8	51.4	44.4	37.2	27.7	43.7
	MEAN DEW POINT	14	27.5	28.8	33.0	36.4	40.6	42.8	43.3	42.4	40.1	35.9	32.5	24.5	35.7
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	0.8	5.3	14.4	11.7	2.6	0.1	0.0	0.0	34.9
	MAXIMUM ≤ 32°	30	8.6	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	8.1	21.7
	MINIMUM ≤ 32°	30	20.1	14.5	8.8	3.2	0.1	0.0	0.0	0.0	0.2	3.1	10.8	19.7	80.5
	MINIMUM ≤ 0°	30	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	3.1
H/C	NORMAL HEATING DEG. DAYS	30	977	722	626	441	226	71	15	23	145	391	705	952	5294
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	6	107	260	240	88	0	0	0	701
RH	NORMAL (PERCENT)	30	77	73	63	58	52	46	36	38	47	59	74	78	58
	HOUR 04 LST	30	79	78	73	71	68	63	53	53	61	70	78	80	69
	HOUR 10 LST	30	77	71	60	52	47	41	33	36	42	54	72	78	55
	HOUR 16 LST	30	73	63	49	42	37	31	23	26	32	44	68	76	47
	HOUR 22 LST	30	79	76	68	62	56	49	37	40	51	64	77	80	62
S	PERCENT POSSIBLE SUNSHINE														
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	60	7.4	4.9	1.9	0.3	0.2	0.1	0.0	0.0	0.2	1.0	6.0	8.5	30.5
	THUNDERSTORMS	60	0.0	0.0	0.2	0.9	1.8	1.9	1.9	2.0	1.1	0.3	0.1	0.0	10.2
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1					6.4				3.2				
	MIDNIGHT-MIDNIGHT (OKTAS)	1										3.2			
	MEAN NO. DAYS WITH:														
	CLEAR	1	1.0	3.0	4.0		5.0	7.0							
	PARTLY CLOUDY	1		3.0	2.0		5.0	3.0							
	CLOUDY	1	3.0	2.0	9.0		10.0	3.0							
PR	MEAN STATION PRESSURE(IN)	24	28.53	28.48	28.40	28.42	28.40	28.39	28.40	28.39	28.44	28.49	28.48	28.54	28.45
	MEAN SEA-LEVEL PRES. (IN)	14	30.16	30.13	30.04	30.01	29.97	29.96	29.96	29.95	29.99	30.06	30.10	30.19	30.04
WINDS	MEAN SPEED (MPH)	33	7.3	7.8	8.8	9.5	9.2	9.1	8.8	8.4	8.0	7.4	7.7	7.4	8.3
	PREVAIL.DIR(TENS OF DEGS)	19	16	15	26	26	26	26	27	27	14	14	16	16	26
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	2	40	47	55	48	43	32	33	43	33	40	34	41	55
	DIR. (TENS OF DEGS)		29	25	25	25	24	26	26	23	25	25	23	23	25
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1996	1997	1996	1997	1997	1996	1996	1996	MAR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	2	47	57	63	53	51	40	39	59	40	49	48	48	63
	DIR. (TENS OF DEGS)		27	25	25	25	24	23	25	23	16	24	16	23	25
	YEAR OF OCCURRENCE		1996	1997	1997	1997	1996	1997	1996	1997	1997	1996	1996	1996	MAR 1997
PRECIPITATION	NORMAL (IN)	30	1.51	1.14	1.16	1.04	0.99	0.64	0.35	0.53	0.59	0.86	1.58	1.63	12.02
	MAXIMUM MONTHLY (IN)	62	3.92	3.03	2.82	2.78	3.18	2.70	1.45	2.58	2.34	2.79	3.76	4.68	4.68
	YEAR OF OCCURRENCE		1970	1940	1983	1978	1991	1947	1993	1977	1941	1947	1973	1973	DEC 1973
	MINIMUM MONTHLY (IN)	62	0.21	0.07	0.24	0.01	0.03	0.03	T	0.00	T	T	0.04	0.21	0.00
	YEAR OF OCCURRENCE		1949	1964	1941	1956	1964	1986	1967	1969	1993	1987	1939	1989	AUG 1969
	MAXIMUM IN 24 HOURS (IN)	62	1.29	1.41	1.33	1.24	1.52	1.49	1.19	2.19	1.23	1.88	1.35	1.25	2.19
	YEAR OF OCCURRENCE		1956	1994	1983	1990	1972	1947	1948	1993	1981	1982	1971	1978	AUG 1993
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	12.0	10.9	10.6	8.7	7.2	5.8	2.9	3.6	4.7	6.1	11.7	12.2	96.4
	PRECIPITATION ≥ 1.00	30	*	0.0	*	0.1	*	0.0	0.0	*	*	*	*	*	0.1
SNOWFALL	NORMAL (IN)	30	6.1	2.1	1.0	0.1	T	0.0	0.0	0.0	0.0	0.2	2.2	5.2	16.9
	MAXIMUM MONTHLY (IN)	61	41.6	16.8	4.9	2.2	T	T	T	0.0	0.0	3.2	14.9	26.6	41.6
	YEAR OF OCCURRENCE		1950	1994	1971	1975	1993	1994	1993			1973	1985	1983	JAN 1950
	MAXIMUM IN 24 HOURS (IN)	61	13.3	16.1	4.0	2.2	T	T	T	0.0	0.0	3.2	8.0	9.9	16.1
	YEAR OF OCCURRENCE		1950	1994	1970	1975	1993	1994	1993			1973	1977	1948	FEB 1994
	MAXIMUM SNOW DEPTH (IN)	49	16	12	6	0	0	0	0	0	0	2	8	11	16
	YEAR OF OCCURRENCE		1957	1994	1993							1971	1978	1985	JAN 1957
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	2.2	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.9	5.9

published by: NCDC Asheville, NC

NORMALS, MEANS, AND EXTREMES

SPOKANE, WA (GEG)

LATITUDE: 47° 37' 17" N | LONGITUDE: 117° 31' 40" W | ELEVATION (FT): GRND: 2357 BARO: 2360 | TIME ZONE: PACIFIC (UTC+ 8) | WBAN: 24157

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	33.2	40.6	47.7	57.0	65.8	74.7	83.1	82.5	72.0	58.6	41.4	33.8	57.5
	MEAN DAILY MAXIMUM	50	31.8	39.0	47.3	57.0	66.4	74.1	83.2	82.1	72.5	58.2	41.5	33.2	57.2
	HIGHEST DAILY MAXIMUM	50	59	63	71	90	96	101	103	108	98	86	67	56	108
	YEAR OF OCCURRENCE		1971	1995	1960	1977	1986	1992	1967	1961	1988	1997	1975	1980	AUG 1961
	MEAN OF EXTREME MAXS.	50	45.9	51.5	61.5	73.4	84.2	90.2	96.5	95.8	88.6	75.2	55.6	47.5	72.2
	NORMAL DAILY MINIMUM	30	20.8	25.9	29.6	34.7	41.9	49.2	54.4	54.3	45.8	36.0	28.8	21.7	36.9
	MEAN DAILY MINIMUM	50	20.4	25.2	29.5	35.2	42.7	49.4	54.8	54.3	46.3	36.5	28.6	22.4	37.1
	LOWEST DAILY MINIMUM	50	-22	-24	-7	17	24	33	37	35	24	10	-21	-25	-25
	YEAR OF OCCURRENCE		1979	1996	1989	1966	1954	1984	1981	1965	1985	1991	1985	1968	DEC 1968
	MEAN OF EXTREME MINS.	50	-.4	7.0	15.9	25.7	31.2	38.9	44.4	43.6	33.7	24.0	13.5	2.2	23.3
	NORMAL DRY BULB	30	27.1	33.3	38.7	45.9	53.9	62.0	68.8	68.4	58.9	47.3	35.1	27.8	47.3
	MEAN DRY BULB	50	26.1	32.0	38.4	46.1	54.5	61.8	69.0	68.2	59.5	47.4	35.1	27.8	47.2
	MEAN WET BULB	13	27.1	29.2	35.6	41.1	47.2	52.1	55.6	50.7	49.3	41.2	32.8	25.9	40.6
	MEAN DEW POINT	13	24.8	25.4	29.9	33.7	39.0	43.3	44.7	40.3	40.0	34.7	30.1	23.7	34.1
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	0.3	2.1	8.4	7.2	1.0	0.0	0.0	0.0	19.0
	MAXIMUM ≤ 32°	30	14.2	4.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.1	13.8	37.7
	MINIMUM ≤ 32°	30	26.5	22.4	20.8	10.7	1.7	0.0	0.0	0.0	0.8	9.5	19.9	26.6	138.9
	MINIMUM ≤ 0°	30	2.3	0.5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.1	5.2
H/C	NORMAL HEATING DEG. DAYS	30	1175	888	815	573	344	139	30	56	223	549	897	1153	6842
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	0	49	148	161	40	0	0	0	398
RH	NORMAL (PERCENT)	30	82	79	70	61	58	54	44	45	54	67	83	86	65
	HOUR 04 LST	30	85	84	81	77	76	74	64	63	71	79	87	87	77
	HOUR 10 LST	30	83	80	69	57	53	49	41	43	51	66	83	86	63
	HOUR 16 LST	30	78	69	55	44	41	36	27	28	35	49	76	82	52
	HOUR 22 LST	30	84	81	74	65	63	58	45	46	56	70	85	87	68
S	PERCENT POSSIBLE SUNSHINE	47	28	41	55	61	65	67	80	78	72	55	29	23	54
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	50	9.4	7.1	3.1	1.2	0.8	0.5	0.2	0.3	0.8	4.0	8.6	8.6	44.6
	THUNDERSTORMS	50	0.0	0.0	0.3	0.7	1.6	2.8	2.4	2.1	0.8	0.3	0.1	0.0	11.1
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1			7.2										
	MIDNIGHT-MIDNIGHT (OKTAS)														
	MEAN NO. DAYS WITH:														
	CLEAR	1		2.0	3.0		3.0	6.0							
	PARTLY CLOUDY	1		3.0	2.0		3.0	1.0							
	CLOUDY	1	4.0	3.0	10.0		10.0	4.0							
PR	MEAN STATION PRESSURE(IN)	23	27.58	27.55	27.47	27.49	27.48	27.49	27.52	27.51	27.55	27.58	27.54	27.58	27.53
	MEAN SEA-LEVEL PRES. (IN)	13	30.15	30.12	30.02	29.98	29.94	29.94	29.96	29.95	30.00	30.05	30.08	30.15	30.03
WINDS	MEAN SPEED (MPH)	35	8.5	9.1	9.7	10.1	9.3	9.3	8.7	8.2	8.1	8.1	8.7	8.3	8.8
	PREVAIL.DIR(TENS OF DEGS)	15	05	06	22	22	22	22	22	22	22	22	05	05	22
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	2	37	34	41	46	44	29	34	31	32	38	28	32	46
	DIR. (TENS OF DEGS)		18	22	25	25	26	26	26	25	21	22	24	22	25
	YEAR OF OCCURRENCE		1997	1996	1997	1997	1997	1996	1996	1996	1997	1997	1997	1997	APR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	2	43	41	47	53	48	34	40	39	38	45	32	40	53
	DIR. (TENS OF DEGS)		20	21	25	26	26	23	26	27	20	23	22	22	26
	YEAR OF OCCURRENCE		1997	1996	1997	1997	1997	1997	1996	1996	1997	1997	1997	1997	APR 1997
PRECIPITATION	NORMAL (IN)	30	1.98	1.49	1.49	1.18	1.41	1.26	0.67	0.72	0.73	0.99	2.15	2.42	16.49
	MAXIMUM MONTHLY (IN)	50	4.96	3.94	3.81	3.08	5.71	3.06	2.33	1.83	2.05	4.05	5.10	5.13	5.71
	YEAR OF OCCURRENCE		1959	1961	1995	1948	1948	1964	1990	1976	1959	1950	1973	1964	MAY 1948
	MINIMUM MONTHLY (IN)	50	0.38	0.35	0.31	0.08	0.20	0.16	T	T	T	0.03	0.22	0.60	T
	YEAR OF OCCURRENCE		1985	1988	1965	1956	1982	1960	1994	1988	1990	1987	1976	1976	JUL 1994
	MAXIMUM IN 24 HOURS (IN)	50	1.48	1.11	1.08	1.41	1.67	2.07	1.80	1.09	1.12	1.23	1.41	1.60	2.07
	YEAR OF OCCURRENCE		1954	1963	1995	1997	1948	1964	1990	1959	1973	1994	1960	1951	JUN 1964
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	13.1	10.8	11.1	8.9	9.2	7.7	4.5	5.1	5.7	7.1	12.8	14.7	110.7
	PRECIPITATION ≥ 1.00	30	*	0.0	0.0	0.0	0.0	0.1	*	0.0	*	0.0	*	0.1	0.2
SNOWFALL	NORMAL (IN)	30	14.2	6.7	3.6	0.9	0.2	0.0	0.0	0.0	0.0	0.3	6.4	15.1	47.4
	MAXIMUM MONTHLY (IN)	49	56.9	28.5	15.3	6.6	3.5	T	0.0	0.0	T	6.1	24.7	42.0	56.9
	YEAR OF OCCURRENCE		1950	1975	1962	1964	1967	1994			1991	1957	1955	1964	JAN 1950
	MAXIMUM IN 24 HOURS (IN)	49	13.0	11.0	6.1	4.9	3.5	T	0.0	0.0	T	6.1	9.0	12.1	13.0
	YEAR OF OCCURRENCE		1950	1993	1989	1964	1967	1994			1991	1957	1973	1951	JAN 1950
	MAXIMUM SNOW DEPTH (IN)	48	39	42	16	2	0	0	0	0	0	4	12	23	42
	YEAR OF OCCURRENCE		1969	1969	1969	1990						1957	1985	1951	FEB 1969
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	4.7	2.5	1.4	0.3	0.*	0.0	0.0	0.0	0.0	0.1	2.1	5.0	16.1

NORMALS, MEANS, AND EXTREMES

YAKIMA, WA (YKM)

LATITUDE: 46° 33' 51" N | LONGITUDE: 120° 32' 01" W | ELEVATION (FT): GRND: 1052 BARO: 1068 | TIME ZONE: PACIFIC (UTC+ 8) | WBAN: 24243

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	37.5	46.4	55.2	63.2	71.6	79.3	86.7	85.7	76.8	64.4	48.3	37.5	62.8
	MEAN DAILY MAXIMUM	50	37.1	45.6	55.2	63.7	72.6	79.8	87.4	85.9	77.6	64.3	48.1	37.9	62.9
	HIGHEST DAILY MAXIMUM	51	68	69	80	92	102	105	108	110	100	88	73	67	110
	YEAR OF OCCURRENCE		1977	1947	1960	1977	1986	1992	1971	1971	1988	1992	1989	1980	AUG 1971
	MEAN OF EXTREME MAXS.	50	54.0	59.5	68.0	78.3	89.0	94.4	99.9	98.5	90.8	78.0	62.8	54.6	77.3
	NORMAL DAILY MINIMUM	30	21.8	26.4	30.8	35.5	42.3	49.2	53.1	52.3	44.6	35.3	29.0	22.1	36.9
	MEAN DAILY MINIMUM	50	20.3	25.5	29.9	34.9	42.1	49.0	52.8	51.6	44.1	34.8	27.9	22.3	36.3
	LOWEST DAILY MINIMUM	51	-21	-25	-1	20	25	30	34	35	24	11	-13	-17	-25
	YEAR OF OCCURRENCE		1950	1950	1960	1985	1954	1984	1971	1960	1985	1971	1985	1964	FEB 1950
	MEAN OF EXTREME MINS.	50	1.8	9.3	19.1	24.5	29.5	36.8	41.1	41.2	32.9	23.0	14.7	6.0	23.3
	NORMAL DRY BULB	30	29.7	36.4	43.0	49.4	57.0	64.6	69.9	69.0	60.7	49.9	38.6	29.8	49.8
	MEAN DRY BULB	50	28.7	35.5	42.5	49.3	57.4	64.4	70.2	68.8	60.8	49.6	38.0	30.2	49.6
	MEAN WET BULB	14	28.4	31.8	38.5	43.5	49.4	54.2	58.6	53.7	52.2	43.3	31.6	26.4	42.6
	MEAN DEW POINT	14	23.3	24.9	28.5	34.2	39.6	44.0	48.0	44.5	43.9	36.6	27.5	23.5	34.9
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	1.0	5.0	13.1	10.9	1.7	0.0	0.0	0.0	31.7
	MAXIMUM ≤ 32°	30	9.8	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	8.9	22.2
	MINIMUM ≤ 32°	30	27.3	23.0	19.7	11.5	2.8	0.2	0.0	0.0	1.1	11.2	20.6	27.5	144.9
	MINIMUM ≤ 0°	30	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	3.4
H/C	NORMAL HEATING DEG. DAYS	30	1094	801	682	468	255	90	19	38	169	468	792	1091	5967
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	7	78	171	162	40	0	0	0	458
RH	NORMAL (PERCENT)	30	78	73	61	52	48	47	44	48	56	63	74	80	60
	HOUR 04 LST	30	82	82	76	71	70	69	67	70	75	79	82	84	76
	HOUR 10 LST	30	78	71	55	43	39	38	36	40	45	55	73	80	54
	HOUR 16 LST	30	70	57	40	33	31	30	26	28	32	41	62	74	44
	HOUR 22 LST	30	81	78	67	58	55	53	51	55	64	72	80	82	66
S	PERCENT POSSIBLE SUNSHINE														
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	51	4.8	2.4	0.6	0.1	0.1	0.0	0.0	0.0	0.1	0.7	3.5	6.8	19.1
	THUNDERSTORMS	51	0.0	0.0	0.1	0.4	1.1	1.7	1.4	1.3	0.6	0.1	0.0	0.0	6.7
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	50	6.3	5.9	5.4	5.2	4.7	4.2	2.5	2.7	3.1	4.5	5.8	6.2	4.7
	MIDNIGHT-MIDNIGHT (OKTAS)	29	5.9	5.3	4.7	4.6	4.1	3.8	2.4	2.5	2.8	3.9	5.4	5.8	4.3
	MEAN NO. DAYS WITH:														
	CLEAR	50	4.0	4.4	6.2	6.2	8.4	10.3	18.7	17.5	15.0	9.5	5.1	4.0	109.3
	PARTLY CLOUDY	50	5.4	5.8	8.3	9.4	10.5	9.8	8.0	7.8	7.9	8.3	6.0	5.2	92.4
	CLOUDY	50	21.6	18.0	16.6	14.4	12.1	9.9	4.3	5.6	7.1	13.2	18.9	21.8	163.5
PR	MEAN STATION PRESSURE(IN)	22	29.00	28.93	28.85	28.86	28.83	28.83	28.83	28.82	28.87	28.93	28.94	29.00	28.89
	MEAN SEA-LEVEL PRES. (IN)	14	30.18	30.13	30.04	30.00	29.95	29.95	29.95	29.94	29.99	30.07	30.09	30.19	30.04
WINDS	MEAN SPEED (MPH)	42	5.6	6.4	7.9	8.5	8.4	8.2	8.0	7.6	7.4	6.7	5.9	5.2	7.1
	PREVAIL.DIR(TENS OF DEGS)	18	27	27	27	27	27	26	27	27	27	28	27	26	27
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	1	31	31	33	40	28	30	25	34	31	31	26	26	40
	DIR. (TENS OF DEGS)		02	28	25	30	28	27	31	27	20	21	31	19	30
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	APR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	1	40	37	43	51	32	36	31	41	41	41	33	32	51
	DIR. (TENS OF DEGS)		22	28	19	30	19	26	30	27	20	21	30	19	30
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	APR 1997
PRECIPITATION	NORMAL (IN)	30	1.21	0.74	0.67	0.50	0.45	0.53	0.16	0.40	0.40	0.47	1.03	1.41	7.97
	MAXIMUM MONTHLY (IN)	51	3.68	2.46	2.63	1.83	2.76	2.53	0.71	2.10	2.07	2.22	2.83	5.59	5.59
	YEAR OF OCCURRENCE		1995	1961	1957	1995	1948	1991	1966	1975	1986	1950	1973	1996	DEC 1996
	MINIMUM MONTHLY (IN)	51	0.09	T	0.01	T	0.03	0.01	T	0.00	0.00	0.00	T	0.07	0.00
	YEAR OF OCCURRENCE		1985	1988	1973	1985	1964	1970	1988	1955	1986	1978	1990	1976	SEP 1986
	MAXIMUM IN 24 HOURS (IN)	51	1.37	0.87	0.74	1.25	0.90	1.56	0.66	1.74	1.49	1.05	2.03	1.58	2.03
	YEAR OF OCCURRENCE		1963	1961	1987	1974	1986	1982	1963	1990	1986	1982	1996	1977	NOV 1996
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	8.8	6.9	6.5	4.6	5.0	4.3	2.1	2.9	3.4	4.1	8.5	10.0	67.1
	PRECIPITATION ≥ 1.00	30	0.1	0.0	0.0	*	0.0	*	0.0	0.1	*	*	*	0.1	0.3
SNOWFALL	NORMAL (IN)	30	7.7	2.7	1.3	T	T	0.0	0.0	0.0	0.0	0.1	2.2	9.5	23.5
	MAXIMUM MONTHLY (IN)	51	26.6	16.5	10.8	0.2	T	0.0	0.0	0.0	0.0	2.9	23.5	37.5	37.5
	YEAR OF OCCURRENCE		1950	1949	1971	1993	1994					1991	1996	1964	DEC 1964
	MAXIMUM IN 24 HOURS (IN)	51	13.6	8.2	7.4	0.2	T	0.0	0.0	0.0	0.0	2.4	18.9	14.0	18.9
	YEAR OF OCCURRENCE		1963	1994	1951	1993	1994					1991	1996	1964	NOV 1996
	MAXIMUM SNOW DEPTH (IN)	49	21	15	7	0	0	0	0	0	0	2	9	19	21
	YEAR OF OCCURRENCE		1997	1969	1969							1991	1984	1964	JAN 1997
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	2.4	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	3.0	7.6

NORMALS, MEANS, AND EXTREMES

PENDLETON, OREGON

LATITUDE: 45°41'N LONGITUDE: 118°51'W ELEVATION: FT. GRND 1462 BARO 1507 TIME ZONE: PACIFIC WBAN: 24155

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		39.4	46.9	53.4	61.4	70.6	79.6	88.9	85.9	77.1	63.7	48.7	42.5	63.2
-Daily Minimum		26.3	31.8	34.4	39.2	46.1	52.9	58.6	57.5	50.5	41.3	33.4	29.5	41.8
-Monthly		32.8	39.4	43.9	50.3	58.4	66.2	73.8	71.7	63.8	52.5	41.1	36.0	52.5
Extremes														
-Record Highest	55	68	72	79	91	100	108	110	113	102	92	77	67	113
-Year		1974	1986	1964	1977	1986	1961	1939	1961	1955	1980	1975	1980	AUG 1961
-Record Lowest	55	-22	-18	10	18	25	36	42	40	30	11	-12	-19	-22
-Year		1957	1950	1955	1936	1954	1966	1971	1980	1970	1935	1985	1983	JAN 1957
NORMAL DEGREE DAYS:														
Heating (base 65°F)		998	717	654	441	220	75	7	27	120	388	717	899	5263
Cooling (base 65°F)		0	0	0	0	16	111	280	235	84	0	0	0	726
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	45	8.4	8.0	7.3	6.8	6.1	5.4	3.0	3.4	4.1	5.8	7.9	8.4	6.2
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	55	2.4	2.7	4.8	5.4	7.5	9.7	19.5	18.0	15.0	10.1	3.5	2.6	101.2
-Partly Cloudy	55	5.2	5.6	7.5	9.4	10.7	10.1	7.6	7.8	7.8	7.9	6.5	4.6	90.8
-Cloudy	55	23.4	19.9	18.6	15.2	12.9	10.1	3.9	5.2	7.2	13.0	20.0	23.8	173.2
Precipitation														
.01 inches or more	55	12.4	10.7	10.8	8.8	7.8	6.5	2.6	3.1	4.4	7.1	11.3	12.6	98.3
Snow, Ice pellets														
1.0 inches or more	55	2.7	1.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.*	0.5	1.4	6.1
Thunderstorms	53	0.0	0.*	0.2	0.8	1.8	1.9	1.8	2.0	1.1	0.3	0.1	0.*	10.0
Heavy Fog Visibility 1/4 mile or less	53	7.2	4.7	1.7	0.3	0.2	0.1	0.0	0.*	0.2	1.0	6.0	8.6	30.2
Temperature °F														
-Maximum														
90° and above	55	0.0	0.0	0.0	0.*	0.8	4.6	14.4	10.6	2.7	0.*	0.0	0.0	33.1
32° and below	55	9.3	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	7.4	21.8
-Minimum														
32° and below	55	21.2	15.8	9.5	2.5	0.1	0.0	0.0	0.0	0.1	2.5	12.3	19.3	83.4
0° and below	55	1.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	3.1
AVG. STATION PRESS. (mb)	17	966.2	964.7	961.7	962.5	961.9	961.6	961.8	961.3	962.9	964.9	964.1	966.7	963.4
RELATIVE HUMIDITY (%)														
Hour 04	49	80	79	73	71	69	65	54	54	62	72	79	82	70
Hour 10 (Local Time)	51	77	71	59	51	47	42	34	37	43	55	72	79	56
Hour 16	51	75	65	49	42	37	32	23	26	32	47	69	78	48
Hour 22	48	80	77	69	63	58	52	38	41	51	66	78	81	63
PRECIPITATION (inches):														
Water Equivalent														
-Normal		1.73	1.11	1.06	0.99	1.09	0.70	0.30	0.55	0.58	0.95	1.48	1.66	12.20
-Maximum Monthly	55	3.92	3.03	2.82	2.78	3.02	2.70	1.26	2.58	2.34	2.79	3.76	4.68	4.68
-Year		1970	1940	1983	1978	1962	1947	1948	1977	1947	1947	1973	1973	DEC 1973
-Minimum Monthly	55	0.21	0.07	0.24	0.01	0.03	0.03	T	0.00	T	T	0.04	0.21	0.00
-Year		1949	1964	1941	1956	1964	1986	1967	1969	1990	1987	1939	1989	AUG 1969
-Maximum in 24 hrs	55	1.29	1.09	1.33	1.24	1.52	1.49	1.19	1.48	1.23	1.88	1.35	1.25	1.88
-Year		1956	1959	1983	1990	1972	1947	1948	1977	1981	1982	1971	1976	OCT 1982
Snow, Ice pellets														
-Maximum Monthly	55	41.6	15.8	4.9	2.2	T	0.0	0.0	0.0	0.0	3.2	14.9	26.6	41.6
-Year		1950	1936	1971	1975	1989					1973	1985	1983	JAN 1950
-Maximum in 24 hrs	55	13.3	9.7	4.0	2.2	T	0.0	0.0	0.0	0.0	3.2	8.0	9.9	13.3
-Year		1950	1949	1970	1975	1989					1973	1977	1946	JAN 1950
WIND:														
Mean Speed (mph)	37	7.9	8.4	9.4	9.9	9.6	9.7	9.0	8.6	8.4	7.7	7.8	7.6	8.7
Prevailing Direction through 1963		SE	SE	W	W	W	W	WNW	SE	SE	SE	SE	SE	SE
Fastest Obs. 1 Min.														
-Direction (!!!)	35	23	25	29	27	27	29	28	27	27	25	27	29	27
-Speed (MPH)	35	49	54	63	77	48	62	46	40	47	49	62	63	77
-Year		1990	1955	1956	1960	1959	1956	1968	1961	1954	1959	1959	1959	APR 1960
Peak Gust														
-Direction (!!!)	7	SW	SW	W	SW	W	W	W	W	W	W	W	W	SW
-Speed (mph)	7	76	52	63	61	60	49	62	55	56	47	58	62	76
-Date		1990	1988	1984	1987	1988	1986	1990	1990	1984	1985	1989	1990	JAN 1990

(!!!) See Reference Notes on Page 68.

NORMALS, MEANS, AND EXTREMES

SPOKANE WASHINGTON

LATITUDE: 47°38'N LONGITUDE: 117°32'W ELEVATION: FT. GRND 2357 BARO 2360 TIME ZONE: PACIFIC WBAN: 24157

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		31.3	39.0	46.2	56.7	66.1	74.0	84.0	81.7	72.4	58.3	41.4	34.2	57.1
-Daily Minimum		20.0	25.7	29.0	34.9	42.5	49.3	55.3	54.3	46.5	36.7	28.5	23.7	37.2
-Monthly		25.7	32.4	37.6	45.8	54.3	61.7	69.7	68.1	59.4	47.6	34.9	29.0	47.2
Extremes														
-Record Highest	43	59	61	71	90	96	100	103	108	98	86	67	56	108
-Year		1971	1958	1960	1977	1986	1973	1967	1961	1988	1980	1975	1980	AUG 1961
-Record Lowest	43	-22	-17	-7	17	24	33	37	35	24	11	-21	-25	-25
-Year		1979	1979	1989	1966	1954	1984	1981	1965	1985	1984	1985	1968	DEC 1968
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1218	913	849	576	339	140	17	63	209	539	903	1116	6882
Cooling (base 65°F)		0	0	0	0	8	41	162	159	41	0	0	0	411
% OF POSSIBLE SUNSHINE	42	27	40	54	61	63	66	80	77	71	55	28	22	54
MEAN SKY COVER (tenths)														
Sunrise - Sunset	43	8.3	8.0	7.4	7.1	6.7	6.1	3.8	4.2	4.8	6.3	8.1	8.4	6.6
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	43	3.0	3.3	4.2	4.5	5.5	7.3	16.5	15.2	12.3	8.0	3.2	2.8	85.7
-Partly Cloudy	43	4.3	5.0	7.8	8.3	10.1	10.3	8.3	8.4	8.1	7.7	5.0	3.9	87.4
-Cloudy	43	23.7	20.0	19.0	17.2	15.4	12.4	6.1	7.4	9.6	15.3	21.8	24.3	192.1
Precipitation .01 inches or more	43	14.2	11.4	11.5	8.6	9.4	7.7	4.3	5.0	5.7	7.6	12.6	15.0	112.9
Snow, Ice pellets 1.0 inches or more	43	5.3	2.9	1.6	0.2	0.*	0.0	0.0	0.0	0.0	0.1	2.0	5.0	17.2
Thunderstorms	43	0.*	0.*	0.3	0.7	1.6	2.9	2.1	2.1	0.7	0.3	0.1	0.0	10.7
Heavy Fog Visibility 1/4 mile or less	43	9.4	7.2	3.0	1.2	0.9	0.4	0.2	0.3	0.8	4.2	8.5	12.2	48.3
Temperature °F														
-Maximum														
90° and above	31	0.0	0.0	0.0	0.*	0.3	2.0	8.8	7.2	1.0	0.0	0.0	0.0	19.2
32° and below	31	14.5	4.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	14.0	38.1
-Minimum														
32° and below	31	26.6	22.7	20.7	10.7	1.7	0.0	0.0	0.0	0.8	9.5	20.0	26.6	139.3
0° and below	31	2.5	0.5	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	5.3
AVG. STATION PRESS. (mb)	17	934.0	932.9	930.0	931.1	930.6	931.0	931.8	931.4	932.7	933.9	932.3	934.4	932.2
RELATIVE HUMIDITY (%)														
Hour 04	31	85	84	81	77	77	74	64	63	71	79	87	87	77
Hour 10 (Local Time)	31	83	80	69	57	53	49	40	43	51	66	83	86	63
Hour 16	31	78	69	55	44	41	36	27	28	34	49	76	83	52
Hour 22	31	84	81	74	65	63	58	45	46	56	70	85	87	68
PRECIPITATION (inches):														
Water Equivalent														
-Normal		2.47	1.61	1.36	1.08	1.38	1.23	0.50	0.74	0.71	1.08	2.06	2.49	16.71
-Maximum Monthly	43	4.96	3.94	3.75	3.08	5.71	3.06	2.33	1.83	2.05	4.05	5.10	5.13	5.71
-Year		1959	1961	1950	1948	1948	1964	1990	1976	1959	1950	1973	1964	MAY 1948
-Minimum Monthly	43	0.38	0.35	0.31	0.08	0.20	0.16	T	T	T	0.03	0.22	0.60	T
-Year		1985	1988	1955	1956	1982	1960	1973	1988	1990	1987	1976	1976	SEP 1990
-Maximum in 24 hrs	43	1.48	1.11	0.96	1.01	1.67	2.07	1.80	1.09	1.12	0.98	1.41	1.60	2.07
-Year		1954	1963	1989	1982	1948	1964	1990	1959	1973	1955	1960	1951	JUN 1964
Snow, Ice pellets														
-Maximum Monthly	43	56.9	28.5	15.3	6.6	3.5	T	0.0	0.0	0.0	6.1	24.7	42.0	56.9
-Year		1950	1975	1962	1964	1967	1954				1957	1955	1964	JAN 1950
-Maximum in 24 hrs	43	13.0	8.9	6.1	4.9	3.5	T	0.0	0.0	0.0	6.1	9.0	12.1	13.0
-Year		1950	1975	1989	1964	1967	1954				1957	1973	1951	JAN 1950
WIND:														
Mean Speed (mph)	43	8.8	9.3	9.7	10.0	9.2	9.2	8.6	8.2	8.3	8.2	8.7	8.6	8.9
Prevailing Direction through 1963		NE	SSW	SSW	SW	SSW	SSW	SW	SW	NE	SSW	NE	NE	SSW
Fastest Mile														
-Direction (!!!)	43	SW	SW	SW	SW	W	SW	SW	SW	SW	SW	SW	SW	SW
-Speed (MPH)	43	59	54	54	52	49	44	43	50	38	56	54	51	59
-Year		1972	1949	1971	1987	1957	1986	1970	1982	1961	1950	1949	1956	JAN 1972
Peak Gust														
-Direction (!!!)	7	SW	S	W	SW	W	SW	SW	NW	SW	SE	SW	NE	SW
-Speed (mph)	7	56	51	52	62	53	49	51	47	47	49	56	51	62
-Date		1986	1987	1988	1987	1986	1989	1989	1984	1987	1985	1990	1990	APR 1987

(!!!) See Reference Notes on Page 68.

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NORMALS, MEANS, AND EXTREMES

YAKIMA WASHINGTON

LATITUDE: 46 °34'N LONGITUDE: 120 °32' W ELEVATION: FT. GRND 1052 BARO 1068 TIME ZONE: PACIFIC WBAN: 24243

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		36.7	46.0	54.5	63.5	72.5	79.9	87.8	85.6	77.5	64.5	48.1	39.4	63.0
-Daily Minimum		19.7	26.1	29.2	34.7	42.1	49.1	53.0	51.5	44.3	35.1	28.2	23.6	36.4
-Monthly		28.2	36.1	41.9	49.2	57.3	64.5	70.4	68.6	60.9	49.9	38.2	31.5	49.7
Extremes														
-Record Highest	44	68	69	80	92	102	103	108	110	100	87	73	67	110
-Year		1977	1947	1960	1977	1986	1961	1971	1971	1988	1988	1989	1980	AUG 1971
-Record Lowest	44	-21	-25	-1	20	25	30	34	35	24	11	-13	-17	-25
-Year		1950	1950	1960	1985	1954	1984	1971	1960	1985	1971	1985	1964	FEB 1950
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1141	809	716	474	254	101	18	46	161	468	804	1039	6031
Cooling (base 65°F)		0	0	0	0	16	86	186	158	38	0	0	0	484
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths) Sunrise - Sunset	44	7.9	7.4	6.8	6.5	5.9	5.3	3.1	3.5	4.1	5.8	7.4	7.9	6.0
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	44	4.2	4.3	6.1	6.2	8.2	10.4	18.9	17.5	14.9	9.4	4.9	4.0	108.9
-Partly Cloudy	44	5.3	6.0	8.3	9.4	10.6	9.7	7.8	7.8	7.8	8.3	6.0	5.3	92.3
-Cloudy	44	21.5	17.9	16.7	14.4	12.2	9.9	4.4	5.7	7.3	13.4	19.0	21.6	164.0
Precipitation .01 inches or more	44	9.4	7.1	6.5	4.5	5.0	4.7	2.0	2.9	3.2	5.0	8.4	9.6	68.5
Snow, Ice pellets 1.0 inches or more	42	2.7	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.*	0.7	2.7	7.9
Thunderstorms	44	0.0	0.*	0.1	0.5	1.1	1.7	1.4	1.3	0.6	0.1	0.0	0.0	6.8
Heavy Fog Visibility 1/4 mile or less	44	4.6	2.3	0.5	0.*	0.1	0.0	0.*	0.0	0.1	0.7	3.3	6.8	18.5
Temperature °F														
-Maximum														
90° and above	44	0.0	0.0	0.0	0.*	1.3	4.7	13.7	10.6	2.3	0.0	0.0	0.0	32.6
32° and below	44	10.3	2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	8.4	22.9
-Minimum														
32° and below	44	28.0	23.8	20.6	11.9	2.8	0.1	0.0	0.0	1.0	10.9	21.2	27.8	148.3
0° and below	44	2.4	0.6	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	4.1
AVG. STATION PRESS. (mb)	17	982.1	979.4	976.8	977.4	976.5	976.2	976.3	975.8	977.7	979.7	979.5	982.4	978.3
RELATIVE HUMIDITY (%)														
Hour 04	43	83	82	77	72	70	70	68	71	77	81	84	85	77
Hour 10 (Local Time)	44	78	70	54	41	39	38	36	39	44	55	73	80	54
Hour 16	44	71	58	41	33	31	31	25	28	32	43	63	75	44
Hour 22	42	81	79	69	58	56	54	51	55	65	74	81	83	67
PRECIPITATION (inches):														
Water Equivalent														
-Normal		1.44	0.74	0.65	0.50	0.48	0.60	0.14	0.36	0.33	0.47	0.97	1.30	7.98
-Maximum Monthly	44	3.66	2.46	2.63	1.62	2.76	2.10	0.71	2.10	2.07	2.22	2.83	4.19	4.19
-Year		1970	1961	1957	1963	1948	1948	1966	1975	1986	1950	1973	1964	DEC 1964
-Minimum Monthly	44	0.09	T	0.01	T	0.03	0.01	T	0.00	0.00	0.00	T	0.07	0.00
-Year		1985	1988	1973	1985	1964	1970	1988	1955	1986	1978	1990	1976	SEP 1986
-Maximum in 24 hrs	44	1.37	0.87	0.74	1.25	0.90	1.56	0.66	1.74	1.49	1.05	1.08	1.58	1.74
-Year		1963	1961	1987	1974	1986	1982	1963	1990	1986	1982	1955	1977	AUG 1990
Snow, Ice pellets														
-Maximum Monthly	44	26.6	16.5	10.8	T	T	0.0	0.0	0.0	0.0	2.4	21.2	37.5	37.5
-Year		1950	1949	1971	1983	1986					1973	1955	1964	DEC 1964
-Maximum in 24 hrs	44	13.6	5.8	7.4	T	T	0.0	0.0	0.0	0.0	2.4	11.2	14.0	14.0
-Year		1963	1956	1951	1983	1986					1973	1984	1964	DEC 1964
WIND:														
Mean Speed (mph)	38	5.7	6.4	7.9	8.6	8.5	8.2	7.8	7.4	7.4	6.6	5.9	5.2	7.1
Prevailing Direction through 1963		W	W	W	WNW	WNW	NW	WNW	WNW	WNW	WNW	W	W	WNW
Fastest Obs. 1 Min.														
-Direction (!!!)	36	25	25	23	29	18	20	24	29	20	31	29	23	28
-Speed (MPH)	36	44	48	48	46	46	47	43	35	38	41	45	48	48
-Year		1962	1967	1956	1961	1961	1955	1968	1988	1959	1988	1955	1955	FEB 1967
Peak Gust														
-Direction (!!!)	7	W	W	W	S	NE	SE	SW		W	SW	NW	NW	NE
-Speed (mph)	7	55	56	51	52	69	51	54	43	49	54	58	53	69
-Date		1988	1985	1988	1989	1985	1987	1990	1989	1988	1990	1989	1990	MAY 1985

!!! See Reference Notes on Page 68.

ANNEX B

HIGHWAY WHEAT AND BARLEY FLOWS WITH AND WITHOUT THE SNAKE RIVER WATERWAY

The four figures presented in this Annex show highways used to transport wheat and barley to railroad- or river-port-based grain elevators. Maps of wheat and barley flows are presented for the Existing Condition Pathway (Base Scenario) and the Natural River Pathway (No-Barge Scenario). The highways are color coded to indicate the number of bushels transported over eastern Washington roads. Grain volumes can be translated to the number of trucks by assuming that each bushel weighs 60 pounds, and the truck capacity is 26 tons. The maps were originally presented in the publicly funded EWITS Report Number 23 (Jessup, Ellis, and Casavant, 1997), which may be obtained at the website for Washington State Unversity (http://ewits.wsu.edu/frames5.htm).

Figure 8. Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)

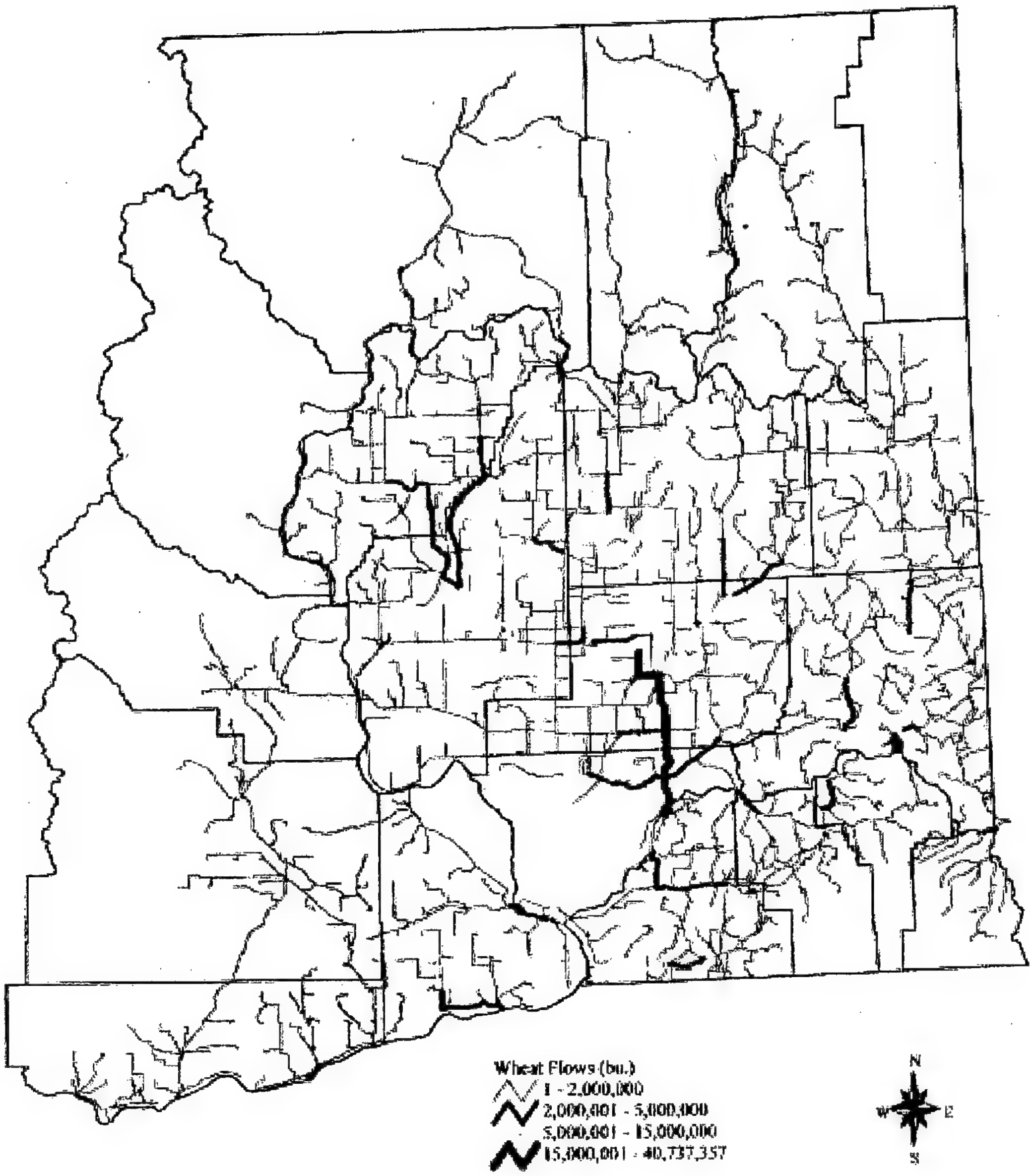

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Figure 9. Optimized Wheat Flows on Eastern Washington Highways (No-Barge Scenario)

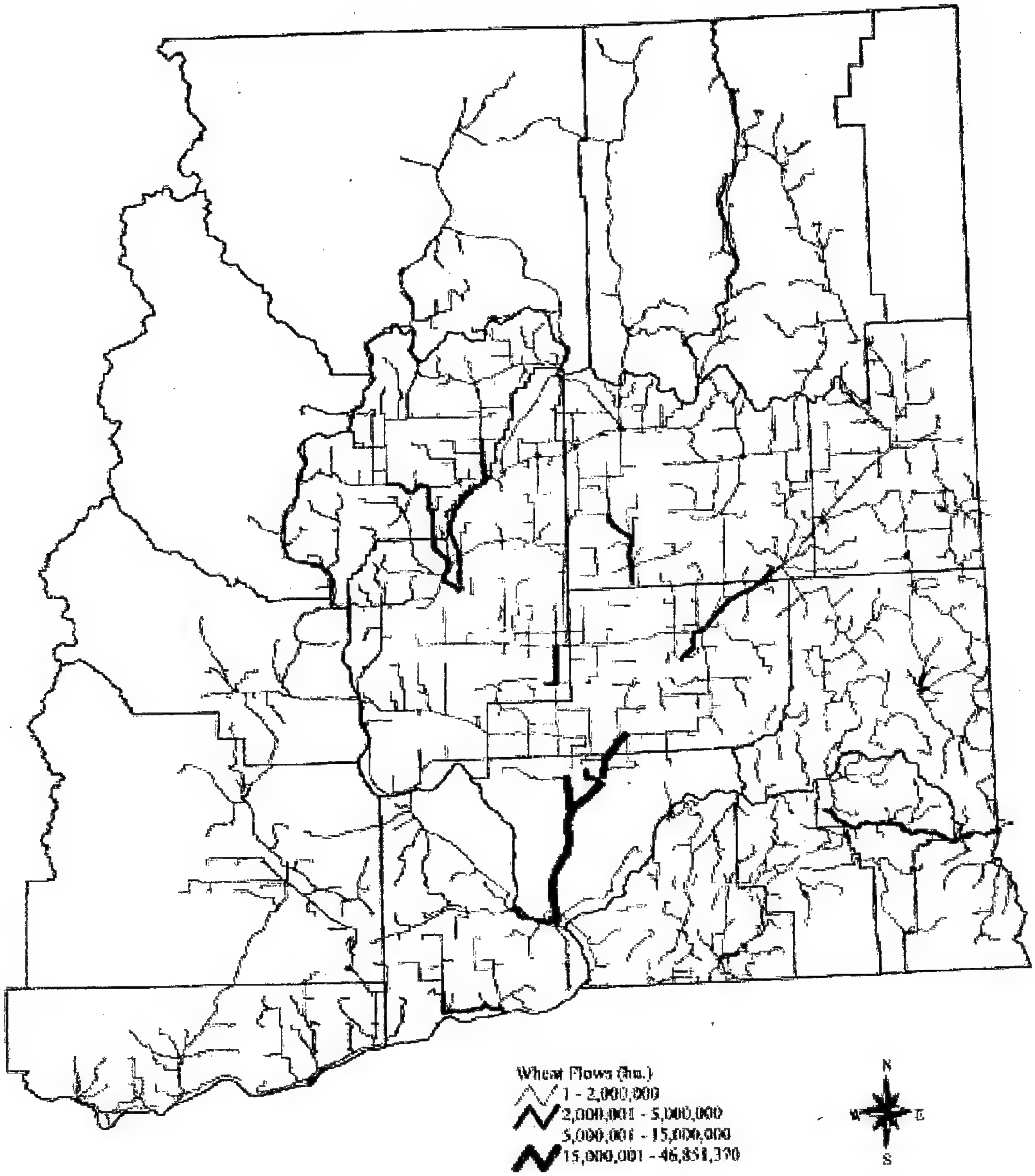

Figure 10. Optimized Barley Flows on Eastern Washington Highways (Base Scenario)

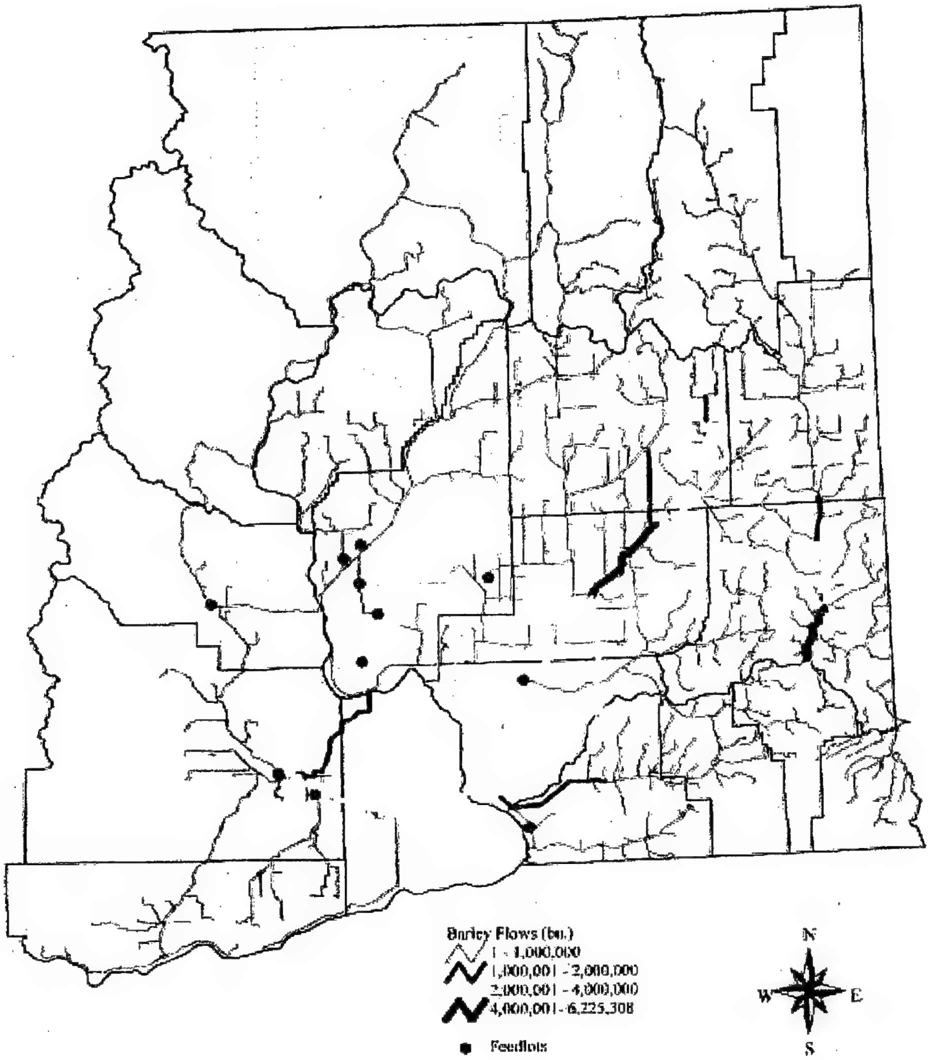

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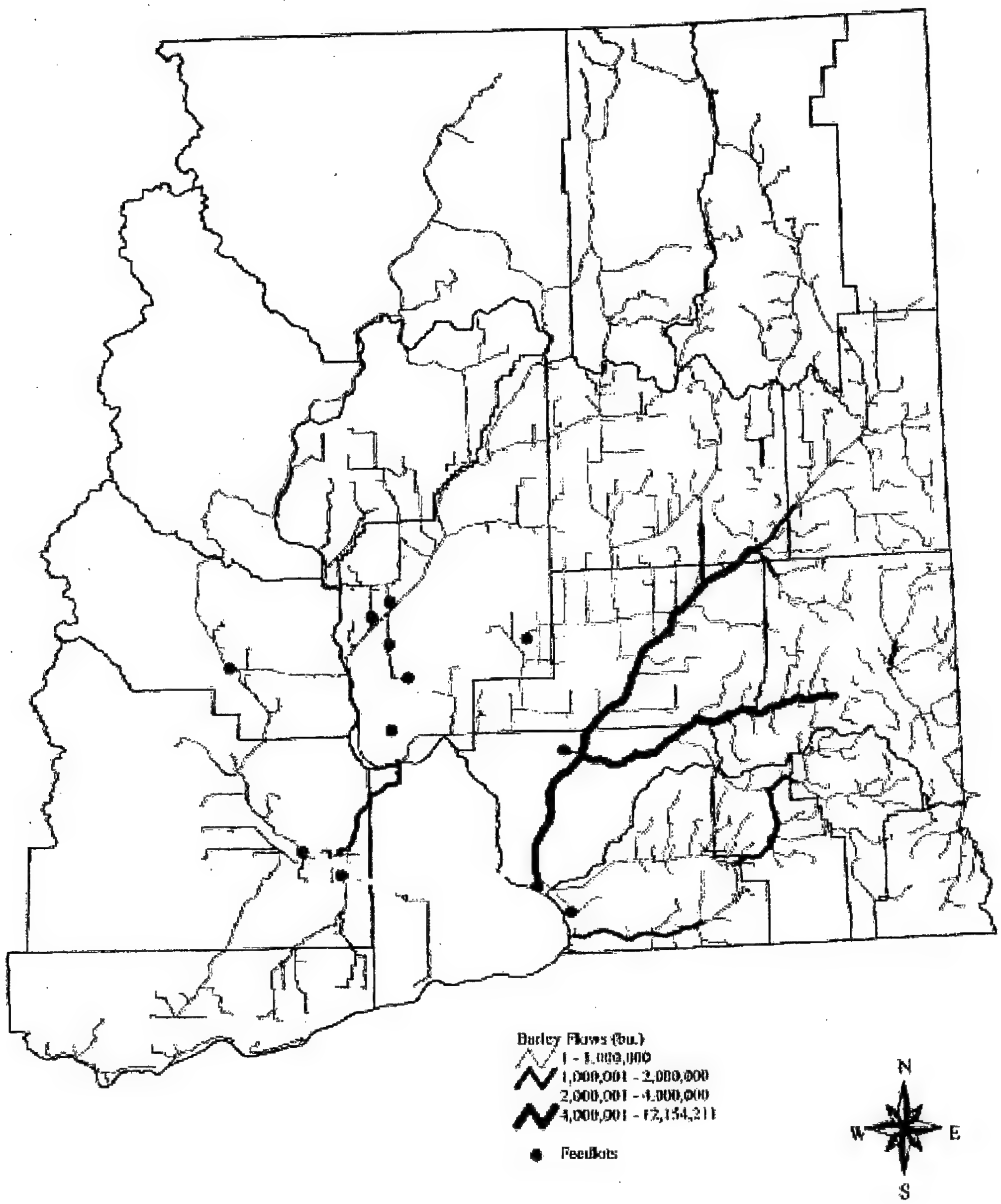
Figure 11. Optimized Barley Flows on Eastern Washington Highways (No-Barge Scenario)



ANNEX C

PREDICTED PM_{10} CONCENTRATIONS FOR TWO 1993 STORM EVENTS

The two figures in this Annex show the distribution of predicted 24-hour PM_{10} concentrations for storms that took place on 3 September and 3 November, 1993. The predictions are part of the CP^3 program and were presented in Claiborn et al., 1998. Additional information on the CP^3 program may be obtained at http://coopext.cahe.wsu.edu/ncp3/.

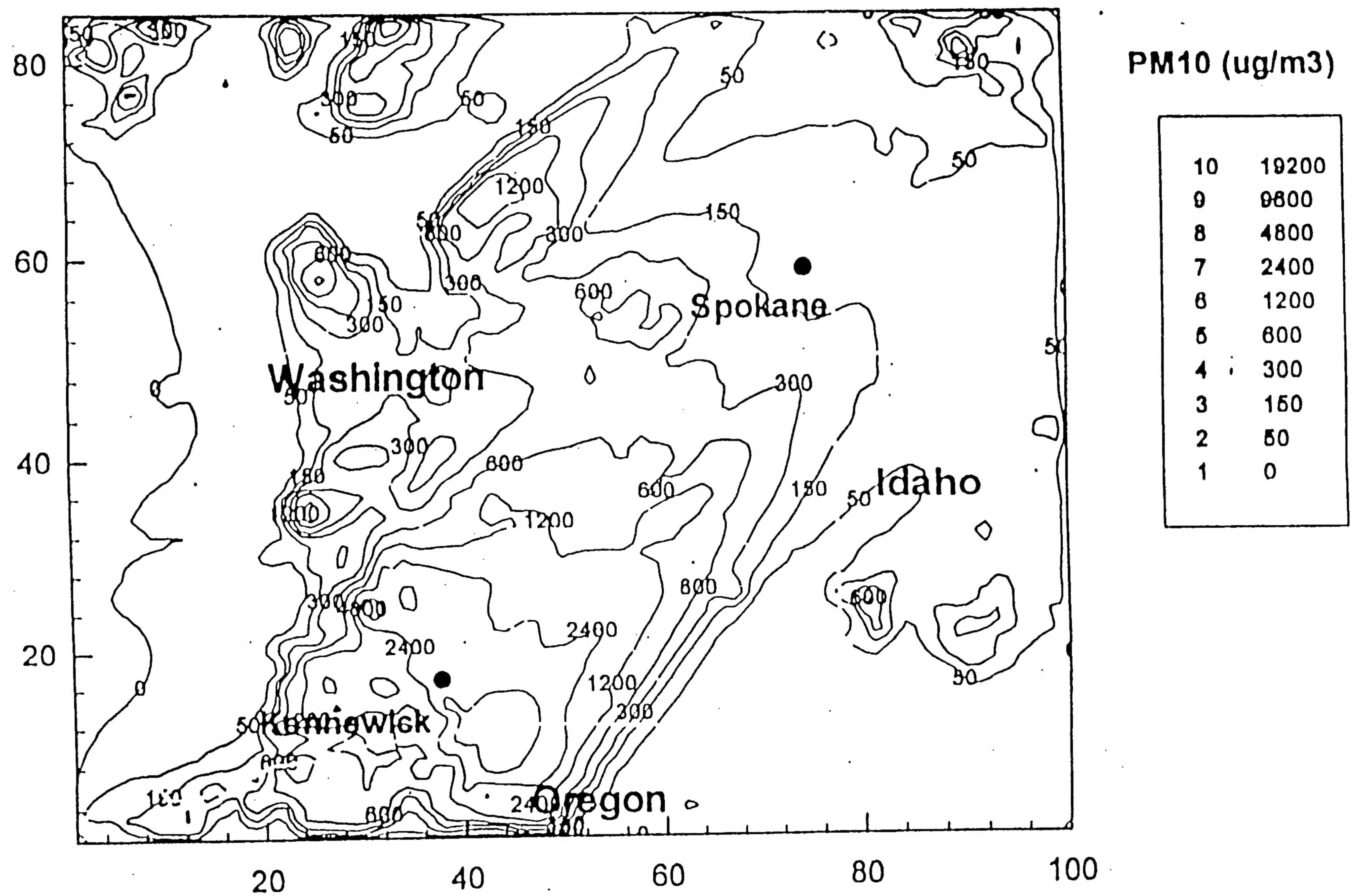


Figure 8. 24 Hour Predicted PM_{10} Concentrations for September 3, 1993

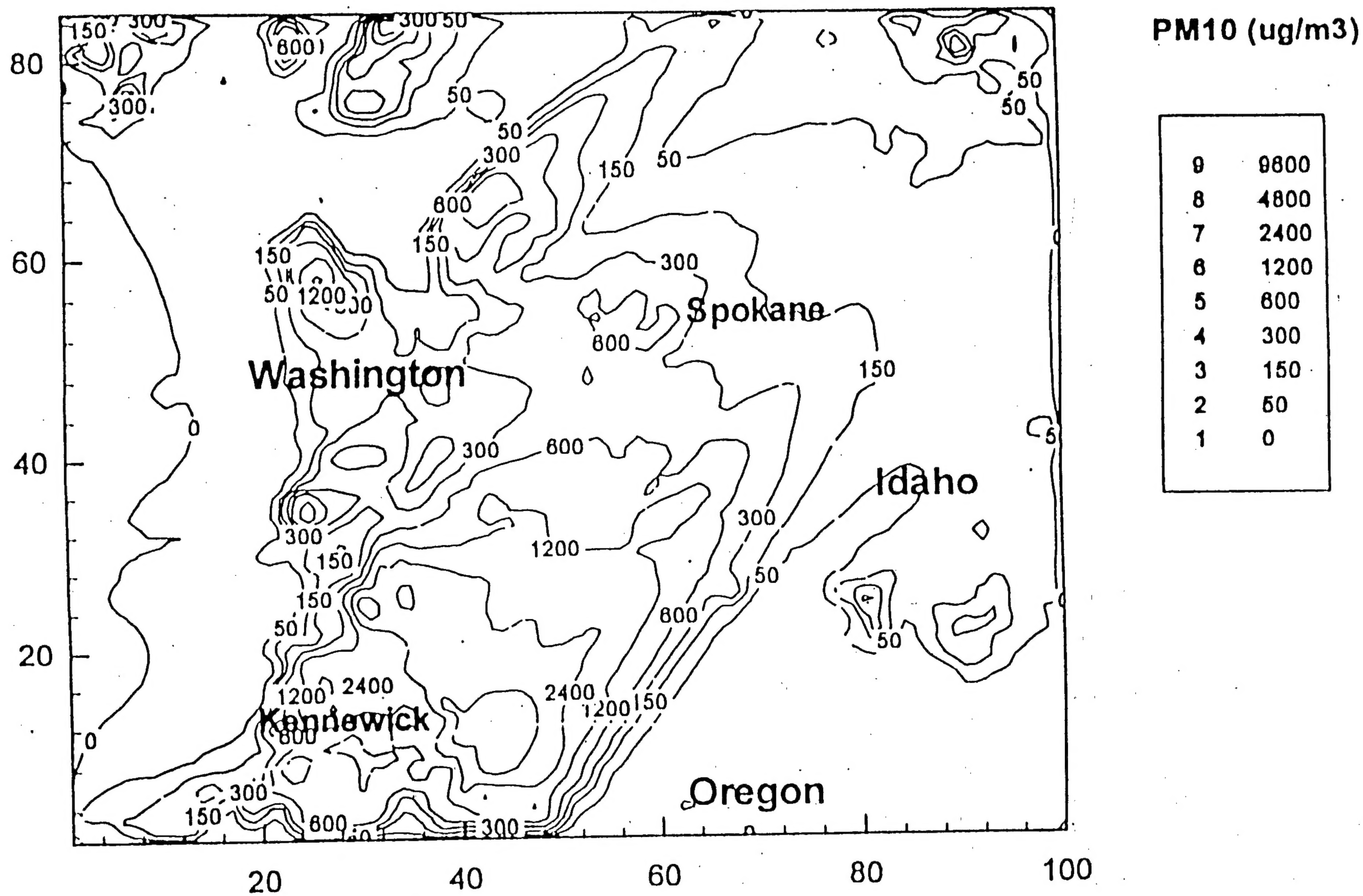


Figure 10. 24 Hour Predicted PM_{10} Concentrations for November 3, 1993